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**STUDY FOR
IDENTIFICATION OF
BENEFICIAL
USES OF
SPACE**

(PHASE I)

**FINAL REPORT - VOLUME II, BOOK 2
TECHNICAL REPORT - RESULTS, CONCLUSIONS
AND RECOMMENDATIONS**

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SUBMITTED PER DPD #296, DR #MA-04


H.L. BLOOM
STUDY MANAGER

APPROVED: 
D.W. KELLER
MANAGER,
ADVANCED NASA PROGRAMS


M.A. CRAMER, JR.
GENERAL MANAGER
ADVANCED SPACE PROGRAMS

SPACE DIVISION
GENERAL  ELECTRIC

Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

PREFACE

This Final Report on Phase I of the Study for Identification of Beneficial Uses of Space (B. U. S.) is comprised of two volumes:

Volume I - Executive Summary

Volume II - Technical Support

Volume II is further subdivided:

- Book 1 - Section I, Introduction; through part of Section III, Specific Study Results.
- Book 2 - Remainder of Section III, Specific Study Results; through Section IV, Conclusions and Recommendations.
- Book 3 - Section V, Appendices A through F.
- Book 4 - Section V, Appendices G through N

Phase I of the Study was conducted from December 1971 to December 1972 by General Electric's Space Division under contract from the Marshall Space Flight Center. Ninety-one working meetings were held with over 400 individuals representing a broad spectrum of U. S. technological capabilities. Participating commercial industries covered such diverse businesses as Aircraft, Building, Chemicals, Electrical Equipment and Utilities, Food, Metals, Paper, Petroleum, etc., Government agencies, universities, and research institutes have also contributed by providing support in such areas as Health, Oceanography and Economics. The methodology employed in gaining and maintaining this technological support, and the results of this effort are reported herein.

These participants initially identified over 100 Ideas for potential products, processes and services which might possibly be developed or produced in space facilities. Further analysis reduced the number of Ideas by an order of magnitude, with those remaining representing

a wide variety of technologies, ranging from high specificity separation techniques, tungsten x-ray targets, and surface acoustic wave components, to testing of prototype fractional horsepower electric motors.

Publication of this report neither implies NASA endorsement of any specific Idea generated during the B. U. S Study, nor a NASA commitment to pursue any program based on these Ideas.

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
	BOOK 1	
	PREFACE.	iii
I	INTRODUCTION	I-1
	I. 1 Review of Study Background.	I-2
	I. 2 Summary of the Study	I-7
	I. 2. 1 Specific Users and Uses	I-7
	I. 2. 2 Benefits	I-13
	I. 2. 3 Time Phasing	I-13
	I. 2. 4 Commonalities.	I-13
	I. 3 Significant Points in the Technical Report	I-16
	I. 4 Summary of Recommendations	I-19
II	METHODOLOGY	II-1
	II. 1 Approach	II-1
	II. 2 Study Tasks	II-6
	II. 2. 1 Study Logic.	II-6
	II. 2. 2 Tasks.	II-8
III	BASIC DATA GENERATED AND SIGNIFICANT RESULTS	III-1
	III. 1 Continuing Identified Ideas	III-3
	BOOK 2	
	PREFACE	iii
	III. 2 Identified Ideas Recommended for Future Considerations	III-132
	III. 3 Other Identified Ideas	III-158
	III. 4 Integrated Time Phasing	III-245
	III. 4. 1 Analysis	III-247
	III. 4. 2 Laboratory Experiments	III-247
	III. 4. 3 Zero-G Tests in Aircraft, Drop Towers, and Sounding Rockets	III-247
	III. 4. 4 Space Experiments	III-248
	III. 4. 5 Operational Phases	III-249

TABLE OF CONTENTS (Cont'd).

<u>Section</u>	<u>Page</u>
III.5 Commonality Analysis.	III-250
III.5.1 Commonalities in Goals, Objectives, Issues, Needs Problem Areas, Knowledge/Capability Requirements and Timing.	III-250
III.5.2 Commonalities in Space Experiments/Activities . . .	III-252
III.5.3 Preliminary Estimates of Candidate Combined Missions	III-263
IV CONCLUSIONS AND RECOMMENDATIONS.	IV-1
IV.1 Conclusions	IV-1
IV.1.1 General Conclusions	IV-1
IV.1.2 Specific Conclusions	IV-1
IV.2 Recommendations	IV-5

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
BOOK 1		
I-1	Study Theme	I-3
I-2	Objectives.	I-3
I-3	Categories to Which Study Was Initially Constrained.	I-4
I-4	Steering Committee and Advisory Group Comments	I-5
I-5	Nations Basic Industries Represented by B. U. S. Studies.	I-8
I-6	Categorization of Ideas Initially Noted by Participants	I-9
I-7	Disposition of Identified Ideas - Total Number of Ideas Generated - 101.	I-11
I-8	Continuing Identified Ideas	I-12
I-9	Typical Benefits Occuring from Potential Space-Produced or Developed Products, Processes and Services	I-14
I-10	Recommendations	I-19
II-1	Approach	II-2
II-2	Study Roles and Relationships	II-5
II-3	Study Logic	II-7
II-4	Task 1.0: Identification of Major Problems to Be Solved	II-9
II-5	User Hierarchy	II-11
II-6	Basic Analytical Process.	II-12
II-7	Examples of "Seeds"	II-14
II-8	Identifying the Problem	II-15
II-9	Benefits Analysis Method.	II-18
II-10	Task 2.0: Analysis of Major Problems to be Solved.	II-20
II-11	Summary of Key Knowledge/Capabilities Requirements.	II-21
II-12	Driving Factors Involved in Key Experiments/Activities	II-23
II-13	Summary of Space Experiments/Activities Objectives, Scope, and Guidelines	II-25
II-14	Task 3.0: Desired Time Phasing	II-31
II-15	Typical Development Program Tasks.	II-32
II-16	Task 4.0: Commonality Analysis	II-35
II-17	Commonality Factors	II-36
III-1	Identified Specific Ideas	III-2
III-2	Tentative Schedule for the Development of Printed Circuitry on Crystals for Acoustic Wave Electronics.	III-13
III-3	Summary of Small Forces Study	III-20
III-4	Schedule	III-24
III-5	Users Benefiting from Vibration Testing of Small Motors in Space	III-30
III-6	Time Phasing of a Development Program for Vibration Measurements in Space	III-33

LIST OF ILLUSTRATIONS (Cont'd)

<u>Figure</u>		<u>Page</u>
III-7	Users for Space Processed Turbine Blades	III-42
III-8	Time Phasing of Development Program	III-54
III-9	Cross-Section of Typical X-ray Tube	III-56
III-10	Effect of Oxygen on Ductility of Tungsten	III-58
III-11	Effect of Carbon on Ductility of Tungsten	III-58
III-12	Variation of Ductility Transition Temperature with Grain Size in Refractory Metals	III-59
III-13	Potential Benefits From High Purity Tungsten.	III-61
III-14	Time Phasing of Development Program	III-64
III-15	Proposed Time Phasing of Development Program	III-73
III-16	Potential Beneficiaries from Space Production of Silicon Crystals for Medical and Electric Power Applications	III-80
III-17	Time Phasing of Development Program	III-83
III-18	Typical Layout for Growing Garnet Films on Substrates (After Levinsteen et al.)	III-85
III-19	Relationship Between Chip Area and Defects per Unit Area (Uniformly Distributed)	III-86
III-20	Potential Beneficiaries from the Growth of Epitaxial Crystal Garnets in Space.	III-87
III-21	Development Schedule	III-89
III-22	Potential Space Products	III-92
III-23	Potential Beneficiaries from Production of Amorphous Oxides in Space	III-93
III-24	Tentative Development Plan for Amorphous Oxides	III-95
III-25	Time Phasing of Development Program	III-100
III-26	Isoenzyme Structures	III-103
III-27	Potential In-Space Separation Technique.	III-105
III-28	Tentative Development Plan and Schedule for the Separation of Isoenzymes in Space Environment	III-109
III-29	Human Circadian System.	III-114
III-30	Phase Shifting of Circadian Rhythm in Oral Temperatures of 5 Healthy Adult White Males.	III-119
III-31	Cosinor Display of Astronaut Conrad's Biorhythms in Orbit	III-130
III-32	Tentative Development Program Schedule for Investigations of Exogenous Factors in Space Affecting Circadian Biorhythms	III-131

BOOK 2

III-33	Time Phasing of Development Program	III-149
III-34	Integrated Time Phasing of Space Experiments/Activities.	III-246
III-35	Commonalities in Goals, Objectives, Issues, Needs, Problem Areas, Knowledge/Capabilities and Timing.	III-250
III-36	Tentative Commonality Analysis of Space Experiments/Activities	III-255

LIST OF ILLUSTRATIONS (Cont'd)

<u>Figure</u>		<u>Page</u>
IV-1	Conclusions--Results Vis-A-Vis Aim of Study.	IV-2
IV-2	Typical Questions	IV-6
IV-3	Phase II Objectives.	IV-7
IV-4	Selected Ideas for Phase II Study	IV-7
IV-5	Study Approach	IV-8
IV-6	Milestone Schedule - Phase II	IV-9

III.2 IDENTIFIED IDEAS RECOMMENDED FOR FUTURE CONSIDERATION

This portion of Section III summarizes the available data on those ideas which, for lack of time or "specificness," were not carried through the complete Study Tasks, but which, in the judgment of the study team, appear to possess potential for worthwhile study.

The 12 ideas so treated include:

9 Ideas for Products

- No. 11 Eutectics for Cold Cathodes. The lack of convection in the zero "G" of orbital operations is expected to allow a more uniform growth of microstructure during solidification of eutectics. That uniformity would considerably enhance the uniformity of electron flux from a cathode, thus increasing cathode life. The inability to interest a credible User caused cessation of effort on this Idea.
- No. 14 Higher Purity Fiber Optics. Utilizing levitation melting in zero "G" under the low contamination environment of hard vacuum would be expected to produce optical fibers with minimum contaminants. The increased transmissivity of such fibers was expected to interest fiber optics Users. Such was not the case, and further effort on the Idea was dropped.
- No. 23 Fluidic Wafers. Originally conceived as a process for the low contamination bonding of fluidic wafers into element stacks, the space environment was subsequently determined to be of potentially more use in the casting of composite wafers. Insufficient time then remained to pursue this avenue to completion.
- No. 45* Large Germanium Crystals for Gamma Ray Camera. The potential for growing large crystals in space would be especially advantageous for use in gamma ray cameras, prototypes of which are presently limited to arrays of small crystals. The increased resolution and system simplification achievable with large crystals was attractive, but the limited availability of personnel working on gamma ray cameras in the U. S. inhibited location of a sufficiently interested User to continue.

*Late inputs indicate that this Idea could now be considered in the category "Continuing Identified Ideas."

- No. 90 Improved Batteries and Capacitors. A number of problem areas, related to membranes, electrode surfaces, and seals were uncovered that appeared similar or analogous to problems already under investigation for space processing. Specific requirements, however, were not forthcoming during the study, and effort was terminated.
- No. 92 Optical Filters. The possibilities of fabricating higher precision grating-type and more uniform density-type optical filters through operations in the low vibration and zero "G" environments of space flight were explored by a number of Key Individuals, but no specific User was identified. This effort was, therefore, terminated.
- No. 95 Corrosion-Resistant Electrodes. The possibilities of glass-based electrode materials for long life, high purity electrodes for specialized applications, fabricated by levitation melting and supercooling in an ionizing radiation environment was identified late in the Study. Insufficient time was available to pursue this Idea further and effort was discontinued.
- No. 97 High Strength Carbon-based Filaments for Plastic Reinforcement. The combined zero "G" and hard vacuum of space flight was noted by a group of Key Individuals as possibly helpful in the removal of oxygen and hydrochloric acid from such fibers, thus producing fibers with more uniform properties for special applications. The generality of data and lack of time caused this Idea to be shelved.
- No. 98 New Antibiotics. Representatives of a pharmaceutical User identified the potential synergistic effects of zero "G" and radiation as providing a high probability of mutating antibiotic-producing organisms at a high rate. However, the press of business prevented their further participation, and this Idea was dropped.

3 Ideas for Services

- No. 38 Safe Disposal of Radioactive Wastes. While outside the scope of the Study, this Idea was identified so frequently that future investigation is warranted.
- No. 57 Blood Analysis Service. Past efforts have indicated that separation of blood fractions (by electrophoresis, for example) should be more precise and provide more detail than ground processes. The attempts to locate a specific User interested in such a service, as a commercial venture rather than as a piece of research, were not successful. Although the effort was terminated, the possibilities remain viable.

- No. 101 Enhanced Solar Insolation. The possibilities of space fabrication of large mirrors or lenses to focus the sun's rays on various earth areas were identified by a group of Key Individuals. Although the Idea was considered as outside the scope of the Study, the possibilities of drying or warming such areas appear interesting. Unfortunately, specific requirements were not obtainable within the time frame of the Study and the Idea was dropped.

The following pages provide a summary of the information acquired on each of the above Ideas.

III.2.1 IDEA NO. 11, GROWTH OF EUTECTICS WITH PRECISE MICRO-PROJECTIONS, FOR COLD CATHODES

Goals and Objectives

Develop and manufacture cold cathodes with high emission efficiency of relatively large electron fluxes. To be accomplished through elimination of convection-caused non-uniformities in eutectic composites.

Potential Users

Manufacturers of specialized vacuum tubes such as thyratron trigger tubes; manufacturers of TV picture tubes, vidicon cameras.

Discussion

A eutectic alloy is a metallic composition that has the lowest melting temperature of any other combination of the constituent metals. Upon solidification of the eutectic, the two solid phases separate into various types of microstructures, depending on the nature of the composition and the relative interfacial energy between the two phases. Very uniform geometry, density and distribution of the microstructures can be obtained through unidirectional solidification of the eutectic melt. A common type of structure, the rod-like structure, is of particular interest in electronic applications, such as the field emitters, or specifically the cold cathode. In the cold cathode application, the eutectic combination would consist of a nickel-tungsten alloy. After directional solidification and formation of the rod-like tungsten microstructures, the nickel would be "etched" out, leaving a very uniform and dense set of tungsten projections, each one acting as an individual field emitter. The efficiency of emission would result from the large number of microprojections per unit area, and the ability of each to carry an equal share of the total electron current loading.

The advantage of the space environment in this application derives from the absence of thermal convection in zero gravity. Convective currents during solidification in a 1-G environment is thought to cause localized bifurcation of the rod-like structures, as well as dislocations of structural planes and, thus, to create non-uniformity and irregularity within

the resulting multirod composite. It is theorized that the microgravity environment present in low earth orbit will be sufficiently small to prevent the detrimental convective effects.

Potential Benefits

Several cold cathode applications were investigated. For many of the conventional vacuum tube applications presently using hot filament cathodes, the use of the "eutectic" cold cathode is not economically possible. Television (TV) picture tubes, which are at the upper end of the cost spectrum in the conventional tubes that were considered, showed a possible performance gain but no economic advantage from using the space processed cathode. The gain would accrue from economy in electrical power, which is particularly useful in small battery powered TV receivers, and instant-on capability. Some industrial concerns are producing low power hot filament cathodes. For instance, Sylvania has a low power heater for a 9-inch TV tube rated at 12.6 volts and 80 milliamperes. One-half watt cathodes are not uncommon; however, the life of such devices is limited. Being able to penetrate the 1/2 watt hot cathode market with a reliable, long life cold cathode has been estimated to be worth about 30 cents premium charge (or additional) per cathode. The field emitter, that portion of the cold cathode that would be manufactured in space, would weigh approximately two grams. Therefore, the cost per pound of cathode would be approximately \$136, which is marginal relative to the projected \$160 per pound for the low cost space transportation system. In assessing the pull-through value of the cold cathode for the TV application, it was pointed out by the GE Co. Television Engineering Department that the additional price per set that would be possible through the cold cathode development may be cancelled by the fact that the TV tube would require a more expensive electronic assembly. Another application that was suggested by Dr. John Houston, GE Co. Corporate Research and Development, was the use of very large area cold cathodes in laser injectors, where very large electron currents are required. The relatively small number of gas lasers that would utilize this development would not warrant an extensive analysis of economic benefits to the manufacturers of laser injectors. However the potential importance of this type of laser in controlled fusion reactors for electrical power generation would definitely warrant consideration of the cold cathode in any future study. Further investigation of this application as part of the B. U. S. Study was discontinued.

III.2.2 IDEA NO. 14, HIGH PURITY FIBER OPTICS MATERIALS

Goals and Objectives

Production of low loss fiber optics achieved by non-contaminating levitation melting to produce high purity glass fibers.

Potential Users

Optical Industry, Blind Instrumentation Manufacturers, Chemical Industry

Discussion

The transmission of light through optical fibers is adversely influenced by scattering from contaminants as well as from wall imperfections. Superior glass fibers may be possible from levitation melting in clean, high vacuum space environment, and the related ability to melt and cool the glass rapidly.

A basic consideration for discontinuing this idea was the lack of an interested User. The fiber attenuation is a function of impurities as well as other factors (such as wall roughness). The possibilities for space processing include crucible-less melting, but the removal of internal contaminants requires further evaluation. The identification of a firm requirement for improved fibers would warrant a more detailed evaluation.

III.2.3 IDEA NO. 23, FABRICATION OF FLUIDIC WAFERS (IMPROVED BONDING OF WAFERS IN FLUIDIC STACKS)*

Goals and Objectives

Fabrication of fluidic wafers with high strength, high temperature capabilities, through the processing of composites not feasible in ground facilities. (Attain higher reliability in fluidic stacks through improved diffusion bonding techniques in a vacuum.)*

Users

Medical Devices Manufacturing Industry, Heavy Equipment Industry, Consumer Appliances, Process Control Industry.

Discussion

Fluidics utilizes the fluid phenomena of wall attachment and stream interaction in components performing sensing, logic and control functions. Active fluidic elements are categorized functionally as amplifiers, sensors, transducers, and logic elements. The latter include an impressive array of devices such as switches, oscillators, and pulse converters. The mechanical simplicity of these devices makes them very rugged even in the most severe temperature, vibration or radiation environments. This environmental tolerance makes fluidic systems particularly suitable in control and measurement applications where the control mechanism or circuit cannot be isolated from the environment, or where the stringent reliability requirements preclude the use of more conventional systems.

Among the principal factors to consider in the manufacture of fluidic components are:

1. Accuracy of machining the flow path and cavities of the wafers comprising the fluidic stack
2. Perfection of bonding of the wafers to form a stack
3. The proper selection of materials for each specific application.

*The initial effort on this idea, bonding of stacks, was subsequently re-oriented to fabrication of the wafers.

Initial effort on this application as part of the B.U.S. Study was in improving the diffusion bonding through use of a cleaner environment that would prevent contamination on the surface of the wafers. The study analysis showed that the controlled atmosphere and cleanliness required in critical steps assembly of the wafer are feasible on earth-based manufacturing facilities. No specific use of this space environment was identified, therefore, for the diffusion bonding process. Similarly, no match was found between the accurate machining of the wafer and the space environment; the process used most extensively (photo-etching) is very satisfactory.

After a brief analysis of the potential of the space environment with respect to fluidic component material selection, it was concluded that this fluidic application merits further study. The following section is a summary describing the possible manufacture of very specialized materials for fluidic components.

Materials for Fluidic Applications. The choice of material depends on many considerations including cost; intricacy (design complexity) and tolerances; method of bonding, mechanical properties (e. g., stability of surface finish; fatigue strength); and dimensional stability under operating conditions. The requirements of each application must decide the type of material needed and the metallurgical process for obtaining the desired properties. Developments in fluidics are rapid and the need for applications in many different environments require fluidic components made of very specialized materials which combine various metallic and non-metallic elements not easily alloyed through conventional melt processes.

For fluidic elements, density is very important for surface homogeneity. Leakage of fluid into adjacent interstices or voids may cause undesirable circuit performance. Density here means the percent of the theoretical density that could be obtained from a perfect composite with porosity. A relative density of 85 to 90 percent should be sufficient to prevent fluid losses through the material. Higher densities are required for good circuit performance.

Powder metallurgy restricts the design of fluidic elements. Thin parts may break and narrow deep sections may not be formable. These limitations may make the process unsuitable for fluidic elements with high aspect ratios and delicate splitters.

Potential Space Processing Techniques. Composite materials not feasible in a 1-G environment may likely be processed in space. These materials include new alloys, metal reinforced ceramics, and ceramic-metal composites (cermets). Certain of these new materials could be made through composite casting, not possible in a 1-G environment due to gravity-induced segregation. The space environment may be advantageous to powder metallurgy in cases where blending powders of very dissimilar densities would produce porosity and inhomogeneities in 1-G because of settling.

In the weightless environment, it may be possible to fill molds of highly intricate shape either by pressure or electromagnetic forces which could not be filled on the earth due to difficulties in positioning the mold so as to exert optimum forces to fill the channels. On earth, the mold problem is centered on overcoming the resistance of liquids to fill channels due to surface tension forces through the combined effect of the weight of the liquid and pressure. In a free environment, new forces (electromagnetic, magnetic, etc.) may be applied uniformly in different directions to help solve this problem.

Potential Benefits

With respect to the ability to improve the quality of bonding of fluidic wafers, the analysis showed that space offers no distinct advantage. Further effort in this aspect of the fluidic application was discontinued.

The potential use of space in processing materials for fluidic stacks warrants further study. In view of this potential, various benefit areas, where fluidic controls made of new materials may be required, are subsequently listed.

1. Medical Applications

- a. Control of flow of body fluids (e.g., artificial heart pump)
- b. Control of artificial limbs and organs (e.g., actuation)
- c. Sensing and measuring temperature, pressure and heart beat

2. Heavy Equipment Industry
 - a. Locomotive control and sensing
 - b. Steam or gas turbine control and sensing
 - c. Commercial aircraft actuator controls
3. Consumer Appliances
 - a. Power generation/transmission (e.g., central power unit for many fluid-driven appliances)
4. Process Control
 - a. Fluidic computers for control functions
 - b. Sensing of pressure, temperature and flow
 - c. Fluidic control valves for automatic operations

III. 2. 4 IDEA NO. 38, SAFE DISPOSAL OF RADIOACTIVE WASTES

Goals and Objectives

Disposal of radioactive wastes by injection into a solar impact, or other remote, trajectory.

Potential Users

Nuclear fuel processors, electric utilities.

Discussion

Disposal of radioactive wastes without eventual pollution of the environment is currently difficult and expensive. The wastes are often highly corrosive, enhancing the containment problem. As the quantity of waste proliferates in the future, current burial or dumping at sea may no longer be acceptable. By 1980, the rate of generation of such wastes will be 4.5×10^3 KG (5 tons) per year; by 1990, 22.7×10^3 to 91×10^3 KG (25 to 100 tons) per year; and by 2000, 273×10^3 (300 tons) per year.

Disposal to space, particularly by a solar impact trajectory, can be an ideal solution to the disposal problem, but costs may be high. Although the quantities previously listed are quite large, they represent only the waste products, and do not account for the packaging. Launch costs, which will be based on the total payload to be placed into the proper trajectory must take into account such packaging. Typically, to render the radioactive material safe for transportation, present practice is to contain the waste in 7,300 KG (16,000 pound) containers, of which only 1,140 KG (2,500 pounds) is waste. The rest is the ruggedized container and cooling system.

The suggested idea is outside of the B. U. S Study guidelines and thus further consideration as part of the B. U. S. Study was discontinued.

III. 2. 5 IDEA NO. 45, LARGER GERMANIUM CRYSTALS FOR GAMMA RAY CAMERA*

Goals and Objectives

Manufacture large germanium crystals for use as detectors in the gamma ray camera, which has wide application in radiological studies of organs and vascular flow. The objective is to increase the size of high quality, high purity crystals from the 50 x 50 mm size used in current prototypes, to large single crystals 300 x 300 mm in cross section.

Potential Users

Health service organizations and medical research institutions (e. g. , Memorial Sloan Kettering Cancer Center, New York, N. Y.); Radiological equipment manufacturers (e. g. , General Electric Medical Systems Department).

Discussion

The main advantages of the gamma ray camera utilizing a solid state detector, over the conventional "Anger" camera which uses photomultipliers are:

1. Better spatial resolution (3 x 3 mm versus 10 x 10 mm resolution element)
2. Improved spatial discrimination due to elimination of Compton scattering effects

The overall improvement in spatial resolution and signal-to-noise ratio will permit development of better diagnostic and therapeutic techniques through improved observation of dynamic phenomena such as myocardial and blood flow effects. Examples of areas where diagnosis and therapy may be improved are congenital cardio-vascular lesions, aneurysms, septal defects, venous obstructions, vascular stenosis, and ventricular hypertrophy.

*Late inputs indicate that this idea could now be considered in the category "Continuing Identified Ideas."

In static radiological applications the gamma camera will permit earlier detection of pulmonary infarcts, liver secondaries, and other inactive lesions*. Functioning thyroid and brain tumors, which are characterized by a higher concentration of activity than the surrounding tissue will be detected easier with the germanium detector gamma camera.

The present solid state detector being developed at the Memorial Sloan Kettering Cancer Center consists of a slab of high purity germanium, 50 x 50 mm grooved at right angles on opposite sides. Each detecting resolution element is a 3 x 3 mm overlapping area covered by the intersection of two orthogonal ridges. Thus, detection at each element requires the sensing of one row and one column. The desired 300 x 300 mm detector would necessitate an array of 36 blocks each of which would contain $16 \times 16 = 256$ resolution elements. The proposed single germanium crystal (300 x 300 mm) would have the following advantages over the array system:

1. It would eliminate the edge effect due to stacking the 36 detector blocks and aligning these with the collimator.
2. The camera electronics would be simplified, because it would require signal conditioning of a smaller number of discrete detector columns and rows (corresponding to "ridges").
3. Better uniformity of electrical characteristics would be obtained across the face of the single crystal, as compared with a "matched" set of detector blocks.

Other materials, besides high purity germanium, may be suitable for the gamma camera application. Mercury iodide and cadmium telluride afford less spectral discrimination than germanium, but have better radiation absorption characteristics (less scattering), require less volume and simpler temperature control. Germanium was the material selected for this application since it is available and has been proven experimentally**. By contrast,

*McCready, V. R., Parker, R. P., "Clinical Tests on a Prototype Semiconductor Gamma Camera," British Journal of Radiology, 44, 58-62, 1971.

**Detco, J. F., "A Prototype Ultrapure Germanium, Orthogonal Strip Gamma Camera," Symposium on Medical Radioisotope Scintigraphy, Monte Carlo, Monaco, 1972.

for instance, cadmium telluride development for this type of application has yet to overcome severe problems in stoichiometry before it could be used satisfactorily. It is possible that once CdTe crystal characteristics have been enhanced (e. g. , to produce sufficiently long lag times), the manufacturer of large size crystals could employ the same techniques suggested for germanium, as indicated in the following discussions.

Potential Advantages of In-Space Crystal Growth from a Melt. The growth of germanium crystals from solution by the Czochralski method may benefit from a zero gravity environment by reducing contamination from the crucible. Transport mechanisms for crucible impurities such as oxygen include molecular diffusion and thermal convection, where the latter is the predominant factor. By minimizing thermal convection and affording better control of the position of the melt/solid interface relative to the crucible, the contamination may be reduced in zero G. It should be noted, however, that methods are already available for obtaining very high purity germanium crystals in earth-based facilities. For instance, Dr. R. N. Hall, GE Corporate Research and Development, has developed a process to attain less than one part in 10^{12} of impurities in germanium crystals.

The manufacture of large high quality crystals (i. e. , free of imperfections) is significantly affected by the fluid flow in the melt, and it is theorized that minimizing thermal convection in zero G may permit larger, more perfect crystals. The temperature and melt/flow conditions (e. g. , Reynold No.) at the microscopic level at the crystal seed are very critical during crystal formation. For instance, the phenomenon of "back melting" of a small segment of the seed during crystal growth can be caused by hot convective jets originating at the crucible walls and impinging upon the growing crystal. The convective jets may contribute to crystal defects such as striation, point defects, and localized granular structures.

The relationship between crystal imperfections and convective currents in the melt has not been fully established. The most comprehensive analysis of this problem, as it relates to metals, has been the current NASA study by the National Bureau of Standards: "Characterization of Thermal Convection and Crystal Perfection in Metals Grown from the Melt," (see Volume I, Section III. 6).

The following statement from the Summary in the above-mentioned NBS report will show the present status of the investigation:

"It is concluded that the crystal perfection varies as we change fluid flow conditions. However, it is inconclusive to establish that fluid flow is the sole factor in determining crystal perfection. It is desirable . . . to obtain more quantitative data on the correlation between fluid flow and the crystal perfection."

Potential Advantages of Space in Crystal Growth Using Float Zone Method. Float zone refining has been proposed as another potential way of obtaining high quality germanium crystals of large size. As the name implies, float zone refining is used primarily in the purification of material; however, with proper thermal control it can also be used to grow single crystals from a polycrystalline base. The process is initiated by stabilizing the temperature of the germanium material just below the melting point, while temperature gradients in the material are reduced to a minimum. A melt zone is established at the end of the material containing a crystal seed; however, the seed is maintained in the solid state. This melt zone is moved slowly and unidirectionally until it has progressed along the entire material subject, resulting in the growth of a single germanium crystal.

It is theorized that the fluid flow and thermal gradients around the seed or evolving crystal will be able to be controlled better in a convectionless environment. The zero gravity environment, therefore, may permit processing of larger and more perfect crystals. Another potential advantage of the float zone method may be the ability to control the size of the molten zone without the restrictions imposed by gravity. In a gravity field, when the volume of melt becomes larger than the cohesive force in the melt can sustain, the float zone will no longer remain stable. Therefore a zero gravity environment will permit surface tension to maintain the integrity of the melt zone in the germanium material, without the tendency to "spill" or deform.

Potential Benefits

The two principal user areas that would benefit from large scale production of single germanium crystal gamma ray cameras would be the public who would receive better medical

care, and the suppliers of the germanium crystals manufactured in space. The radiological equipment manufacturers in the U. S. would benefit somewhat from an increase in the world market for nuclear scanning devices, but the profit per unit of equipment sold should not be appreciably higher than the present rate.

Benefits to the Public. Health services would be improved with the advent of the gamma ray camera because it would provide the necessary spatial resolution and "noise" rejection capability to diagnose many diseases at an earlier stage of pathological development. For instance, it is anticipated that large scale usage of this new radiological tool would have a beneficial impact in early treatment of neoplasms. It is difficult to predict quantitatively the magnitude of this impact; however, a few facts may serve to scope the neoplastic problem in this country. The U.S. mortality rate due to malignant neoplasm was 149 per 100,000 in 1960, increased slightly to 151 per 100,000 in 1964, and climbed to 303 per 100,000 in 1966.

Large scale use of the gamma camera as a routine clinical tool in health screening might result in earlier detection and treatment of neoplasms, and a reduction in fatalities. Improvements in spatial and spectral performance of the detector crystal through space processing would contribute to this large scale use by:

1. Reducing radioisotopic dosage to the patient
2. Simplifying radiological diagnostic analysis
3. Widening the scope of diagnostic applications

It is anticipated, however, that advances in radioisotopic pharmaceuticals will also be needed to make the camera a routine clinical tool for normal health screening.

Benefits to Germanium Crystal Suppliers. A significant increase in the demand of high quality germanium would be realized if the gamma ray camera went into large-scale production. Each space-processed single crystal detector would weigh 4500 grams, since the

specific gravity of germanium is nearly 5.0 and the crystal dimensions are 300 x 300 x 10 mm. Cost of germanium crystals with less than one part per trillion impurity is \$20 per gram. A reasonable cost in the future for the germanium crystal is \$4 per gram;* therefore, the cost of a single crystal would be \$18,000. To obtain an order-of-magnitude estimate of the demand for the large germanium crystals, it was assumed that 10 percent of the hospitals in the U.S. would want to avail themselves of the gamma ray camera, initially. There are over 27,000 in-patient health facilities in the U.S.; therefore, the minimum number of units sold would be 2,700. At \$18,000 per crystal, the gross revenue is $\$48.6 \times 10^6$ per mission.

Impacts. One of the areas that has impeded the commercial development of the solid state gamma camera is the need for cryogenic temperature operation of the germanium crystals. If a closed loop cooling system is used, the price of the radiological system rises significantly. Use of liquid nitrogen as coolant in an open loop system would be less expensive, but would be less desirable from an operational point of view. The impact of the development of the germanium detector for the gamma camera would, thus, be a required concurrent development effort to obtain a cheaper closed loop cryogenic refrigerant for the large detector.

Development Steps. Figure III-33 shows the main phases in the development of the large germanium crystals for the gamma ray camera. The time phasing is also shown, spanning from 1975 to 1981.

*Based on current cost of lithium drifted germanium crystals.

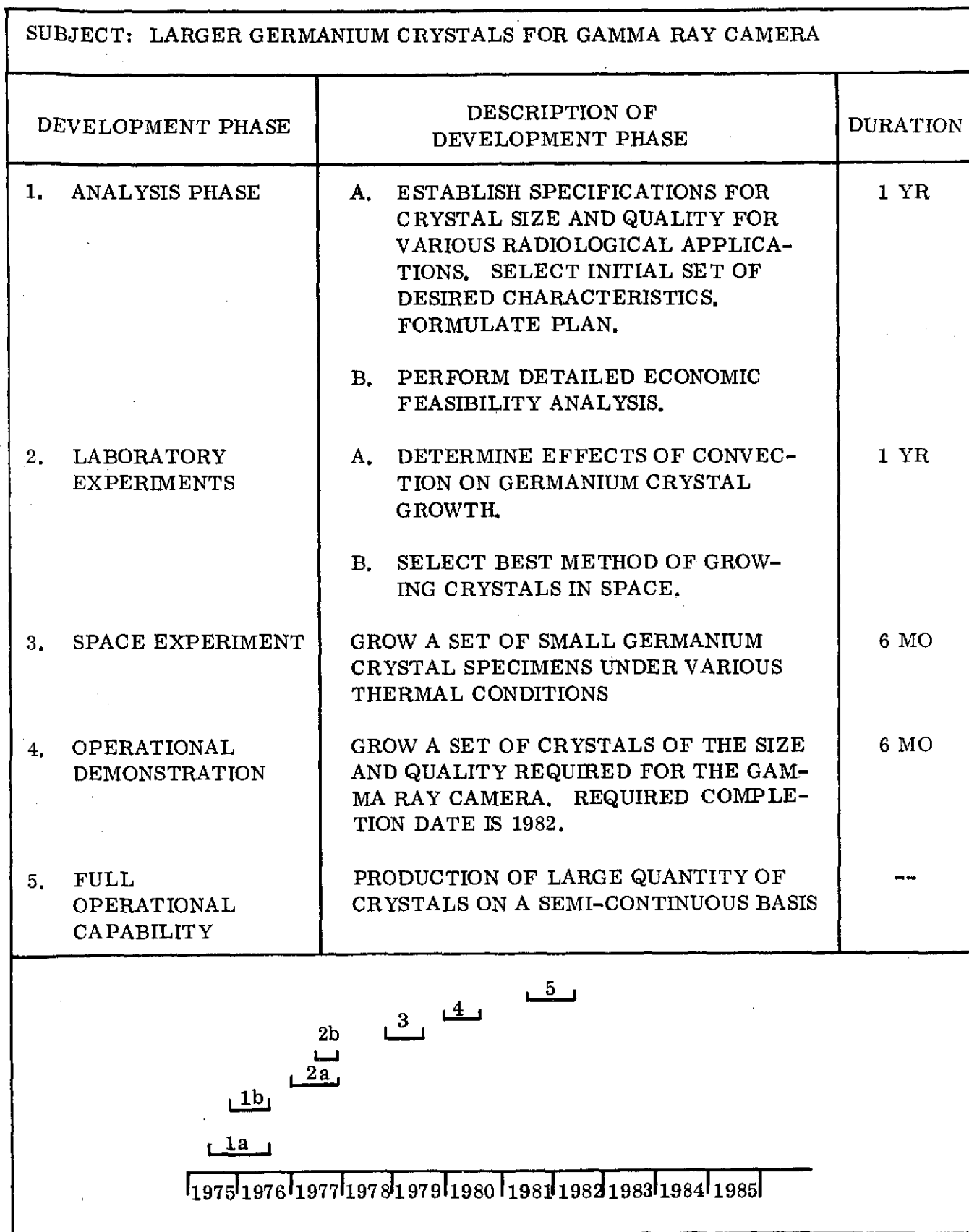


Figure III-33. Time Phasing of Development Program

III.2.6 IDEA NO. 57, BLOOD ANALYSIS

Goals and Objectives

Establishment of a facility to provide improved blood analysis by utilizing high specificity separations not possible on the ground.

Potential Users

Medical Profession, Analytical Laboratories

Discussion

Experimental evidence suggests that improved resolution of blood fractionation may be an important medical service in diagnosing a variety of diseases. For example, changes in the relative and absolute amounts of the various lipoproteins in serum are characteristic of such diseases as nephritis, diabetes, hypothyroidism and hepatitis.

Available blood fraction separation techniques are limited in resolution by gravity-induced convection and sedimentation effects. Performing blood analyses (and analysis of other body fluids) on a regular basis, in the space environment, without gravity-induced limitations, may provide diagnosticians with improved data and certainty in the identification of the various blood fractions related to various human pathologies. Specific user requirements were not identified in the limited time available. However, because of the potential diagnostic improvement benefits, blood analysis is recommended for possible future investigation.

III.2.7 IDEA NO. 90, IMPROVED BATTERIES AND CAPACITORS

Goals and Objectives

Large capacity batteries with superior elements including membranes, ceramic-to-metal seals, electrode surfaces.

Potential Users

Battery and capacitor manufacturers, future electric automobile manufacturers.

Discussion

There is an increasing requirement for larger capacity high reliability batteries. Two types under investigation involved separate but typical problems:

1. A membrane separating a solid electrolyte from a wet amalgam sometimes becomes detached from the electrolyte; keeping the membrane wetted was also a problem (GE).
2. Porous rough plates required are not currently satisfactory (Electric Storage Battery Company).

In all cases, and with capacitors, better ceramic-to-metal seals are desired. Electrode surfaces may also be improved by better quality tungsten oxide surfaces where used, and thinner permeable membranes would be advantageous.

Specific requirements for processing materials were not identified. The Idea was terminated and recommended for possible future consideration when problems are better defined.

III.2.8 IDEA NO. 92, OPTICAL FILTERS - GRATINGS AND VARIABLE DENSITY

Goals and Objectives

Obtain higher precision filters by eliminating effects of earth vibrations on fabricating grating-type, and gravitational effects and contamination on formation of density-type filters.

Potential Users

Instrument manufacturers, various testing laboratories, optical devices manufacturers.

Discussion

Higher accuracy and finer grooving of optical and soft X-ray spectroscopy gratings are potentially possible in space by the elimination of vibrations encountered on earth and the superior electron-beam machining in the high vacuum. Other filters, each as those using controlled particle deposition on, and in, lenses can be improved by the cleaner vacuum and elimination of gravitational loadings during coating and/or lens formation.

This idea was discontinued, but future consideration may be warranted, based on identification of a specific User with specific requirements.

III. 2. 9 IDEA NO. 95, CORROSION-RESISTANT ELECTRODES

Goals and Objectives

Manufacture of non-corroding refractory electrodes of electrically conductive amorphous oxides.

Potential Users

Glass Industry, Chemical & Petroleum Industry, Metal Refineries, etc.

Discussion

The creation and manufacture of non-corroding refractory electrodes of the amorphous oxides (alumina, zirconia, graphite) by levitation melting and exposure to ionizing radiation during supercooling and solidification offers promise of superior electrodes.

Evidence exists in the literature that radiation will change the resistivity of Al_2O_3 by 2.5 ohm meters (10^2 ohm inches) through the introduction of defect structures in the material. If this could be achieved during the supercooling and solidification of the material in a zero gravity, high vacuum environment in space, free of all sources of contamination which might initiate nucleation, one might be able to produce superior electrically conductive high temperature glasses.

The use of refractory electrodes in industry provides a significantly large market, which justifies moderate feasibility testing on the ground to establish the practicality of this idea. Space environment of zero gravity, high vacuum, and possibly, natural radioactive irradiation (or from supplied radioactive sources) would be required for fabrication of such electrodes. The refractory and corrosion resistance characteristics of new amorphous oxides (see Idea No. 60) coupled with electrical conductivity through ionizing radiation-induced defects in their structure should provide better refractory electrodes, with longer life and less batch contamination than currently available.

Unfortunately, the press of other duties for the identifying key individual made further amplification of this idea impossible within the time limits of the B. U. S. Study. The idea was, thus, terminated, although it stimulates speculation about many other possible applications of materials irradiated during solidification.

III. 2. 10 IDEA NO. 97, HIGH STRENGTH CARBON-BASED FILAMENTS FOR PLASTIC REINFORCEMENT

Goals and Objectives

Improved carbon-based long molecule filaments for use in reinforcing thermosetting plastics. The objective is to reduce the imperfections and contaminants in the filament by fabrication in the contaminant free, zero "G" environment of space.

Potential Users

Plastics Industry

Discussion

Current filaments of carbon-based materials are limited in their freedom from oxygen and hydrochloric acid contaminants. Space vacuum would provide a superior capability for this purpose. Zero gravity may also be desirable for uniformity of the material, depending on the process.

Potential Benefits

This idea is cost-compatible because the fibers sell for \$800 per kilogram (nearly \$400 per pound). However, the study has not been pursued to determine whether the improvement in space is sufficiently great to warrant an extensive investigation. Some future evaluation may be considered if a specific user to support the study could be identified.

III. 2. 11 IDEA NO. 98, NEW ANTIBIOTICS

Goals and Objective

Obtain new antibiotics through mutations of the genetic characteristics of the organisms. The objective would be to expose known antibiotic-producing materials to radiation in a zero G environment in an effort to gain a synergistic effect on mutation rates.

Potential User

This Idea was submitted by Smith, Kline and French, and they are very much interested, based upon the known increase in the rate of mutations obtained on the Biosatellite Program through the synergistic effects of zero G and radiation; however, this firm was unable to make available the pertinent personnel to expand this Idea in time to meet the B.U.S. Study schedule. Further investigation appears warranted.

III. 2. 12 IDEA NO. 101, ENHANCED SOLAR INSOLATION

Goals and Objectives

As a more advanced Idea, it was suggested that a very large, order of tens to thousands of kilometers diameter, lightweight mirror or lens, constructed in space, could provide sufficient concentration of solar energy to enable drying or heating of local areas (such as swamps, flooded areas, ice jams, etc.) on the earth.

Potential Users

No Users were identified, and it is suspected that only federal, or at least, regional agencies could likely identify specific requirements.

Discussion

The lack of "G" force in orbit makes possible the concept of very large area structures of miniscule weight per square foot. Furthermore, other forces such as solar "wind", radiation, drag, etc., in orbit are calculable, and could conceivably be employed in the erection, translation, and control of such structures.

This Idea was considered as being out of Study Scope, but with interest from a logical User agency, further Study could define a meaningful future project.

III.3 OTHER IDENTIFIED IDEAS

This portion of Section III summarizes the data obtained on ideas for which work was terminated during the Study for a variety of reasons. In the judgements of the Study team, there was not sufficient justification to warrant further consideration of these items.

The following pages present the available information, arranged in numerical sequence of the idea numbers. No ranking is implied by the sequence.

III.3.1 IDEA NO. 2, FILAMENT MATERIALS FOR HIGH INTENSITY LAMPS

Goals and Objectives

Improve the operating life of filaments in high intensity lamps. The desired characteristics expected to be attained in orbital processing of the tungsten filament material are homogeneity, ductility and the absence of interstitial defects.

Potential Users

Manufacturers of high intensity lamps.

Discussion

In many applications, melt processing of refractory metals has several advantages over powder metallurgy techniques. Examples are:

1. A more homogeneous mixture could be obtained in a melt, when mixing alloys having large percentages of several different elements. Lack of homogeneity in powder metallurgy processes can be attributed to powder blending problems and the slow solid state diffusion process necessary to attain material uniformity.
2. Trace impurities, which may contribute to brittleness, may be reduced through processes such as float zone refining, or through superheating to vaporize the trace elements. Thus, melt processes are compatible with purification techniques that would render the tungsten material more ductile.
3. The imperfect bonding between powder particles may give rise to interstitial defects; these are eliminated by using the liquid phase rather than solid state (powder) process.

The only high temperature melt technique that is being used extensively in refractory metals is drip melting. In this process, cold crucible containing a small molten pool collects the metal that drips from a consumable electrode. Among the disadvantages of the drip method are poor yield; inhomogeneities due to the large temperature gradient, radially from the molten center to the cold outer walls of the crucible, and very slow melting rates. In the space environment, these difficulties would be overcome by melting the levitated tungsten in zero gravity. Uniform RF heating would minimize temperature gradients across the

spherical "ingot", while the absence of settling, buoyancy, and thermal convection would prevent further inhomogeneities or defects due to material segregation.

There is a disadvantage that, unlike the application in the fabrication of high purity tungsten targets for X-ray tubes (see Idea No. 30), makes any melt process infeasible in terms of the tungsten filament application. Namely, traces of potassium, aluminum and silicon must be added to the tungsten powder in order to provide the filament with the desired structural integrity at high temperature. These additives, particularly potassium, would boil off in any melt process due to the high vapor pressure at the elevated melting temperature of tungsten. In the solid state associated with powder metallurgy, the atomic diameter of potassium is sufficiently large to prevent diffusion through the sintered tungsten material. The possibility of developing a new space processed alloy or composite with the desired mechanical properties as tungsten plus additives is not very likely because of the uniqueness of tungsten as the element most suitable for lamp filaments, due to its very high melting temperature, resistivity and mechanical properties.

No meaningful advantage from using the space environment was apparent to the Key Individuals contacted. Further investigation as part of the B. U. S. Study was discontinued.

III.3.2 IDEA NO. 4, AFFINITY CHROMATOGRAPHY

Goals and Objectives

Enable new, more precise, and larger scale enzymic reactions for medical and biological products. The objective is to obtain higher specificity products by eliminating convection and sedimentation effects.

Users

Manufacturers of biologicals, laboratories performing blood fraction analyses, manufacturers of products involving enzyme reactions (i. e., enzyme engineering).

Discussion

Recent advances in the process of binding enzymes into artificial matrixes has opened many possibilities in enzyme engineering, including the selective use from a large spectrum of feasible enzymic reactions, and the selective combination of reactions for performing a given industrial or medical task.

A typical matrix consists of a set of polymer beads capable of holding the particular enzyme(s) in place. The chemical reaction of the substance to be processed takes place at the site of the matrix-bound enzyme, and therefore the output or product of the process does not dilute the processing enzyme. One of the leading processes made possible through the development of matrix-bound enzymes is "affinity chromatography". This is an analytical or purification process which uses biological materials such as enzymes bound upon matrixes such as polymer beads, to separate substances. Several variations of the affinity chromatography have been found effective and depend on the type of substance that is attached to the matrix. For instance instead of enzymes, the matrix-bound substance may consist of antigens; this technique is used in the purification of biological substances such as antibodies, which exhibit affinity with the antigens. Conversely, an antigen-purification process may be established by binding antibodies to the matrix.

The consideration of affinity chromatography as a candidate for detailed separations of substances such as blood fractions was based on the following assumptions:

1. Affinity chromatography depends on the bond that exists between the reacting substance (e.g., enzymes) and the matrix. In some separation processes this bond may be so weak that gravitationally induced effects such as thermal convection, sedimentation and buoyancy may be detrimental to the maintenance of that bond. This may be particularly evident in processes where the covalent bonds between the enzymes and the matrix are dependent on very tenuous opposite electrical charges.
2. In many processes involving affinity chromatography, the product of one enzymic reaction becomes the input to another reaction involving a different biological substance bound to the matrix. Gravitational effects might disturb the optimum sequence of reactions in a given complex chain of reactions wherein several types of enzymes are bound to the same matrix.

The potential use of the space environment in various affinity chromatography processes was discussed with several concerns; namely: Smith Kline and French, Applied Science Laboratories, and the American Biomedical Corporation. No specific user or product-related application was uncovered during those discussions, and the effort was terminated.

III.3.3 IDEA NO. 7, MAGNETRON TUBE MANUFACTURE

Goals and Objectives

Economical production of magnetron tubes for microwave ovens through the use of space vacuum.

Potential Users

Appliance industry.

Discussion

Magnetrons represent one of the few electron tubes not yet replaced by solid state devices. Present production methods include a basic limiting step; i.e., evacuation and sealing of the tube. At present, for each four tubes, a large relatively complex facility is used to accomplish evacuation and sealing, which require a 2 to 4 hour period.

A market volume of thousands of tubes per month is anticipated within the next decade. This production volume will require a major investment in facilities for evacuation and sealing with consequent high operating and maintenance costs. If, as expected, the production volume peaks rapidly or if a solid state replacement becomes available, the facility investment cost must be amortized rapidly, driving up the unit tube cost. Since magnetron tubes are relatively small (1/2 lb), high value items, evacuation and sealing in space was suggested as a possible lower cost alternative.

Although feasible to accomplish using space vacuum, a review of projected production rates revealed peak activity occurring before the availability of a space facility. Therefore further investigation as part of the B. U. S. Study was discontinued.

III.3.4 IDEA NO. 8, SPECIALTY GLASS

Goals and Objectives

To produce high purity glass for various industrial applications such as envelopes for special lamps, optical quality glass, and laser glass. Typical of the impurities to be eliminated or reduced by purification in space were boron, phosphorus, indium, sodium, silicon, chrome, molybdenum and platinum.

Potential Users

Lamp manufacturing industry, manufacturers of refractory optical components, laser system manufacturers.

Discussion

Impurities in glass may degrade the performance and effective life of special lamps. Undesirable trace contaminants also adversely affect the optical characteristics of glass lenses and filters. Effective control of these contaminants requires careful selection of raw material purity and cleanliness precautions during glass manufacture. Even after selecting the prescribed quality of raw material and subjecting the manufacturing process to industrial "clean-room" conditions, the level of purity is found to be inferior to that which is required in some specialized applications.

The analysis considered three ways in which the space environment may be beneficial:

1. Attaining a more perfect "clean room" environment.
2. Driving out the impurities through processes that utilize the space properties of high vacuum and/or weightlessness.
3. Elimination of contamination from the crucible through levitation melting. Of these, only the last was found to have sufficient basis for continuing the Study. The following paragraphs summarize the rationale for this conclusion.

Clean Room Environment. There is no evidence that the degree of cleanliness required for this application could not be attained in advanced earthbased clean room facilities.

Driving Out Impurities. The first method that was considered for eliminating the impurities was to use levitation melting and superheating of the glass, to vaporize and thus boil off impurities. Although this technique may prove effective when dealing with less viscous melts (see analysis section, Idea No. 30), it may not be effective in the case of most glass melts due to their high viscosity and surface tension. In effect, the vaporized substances within the melt may remain trapped, giving rise to bubbling.

Another method that was considered was the use of external forces such as light pressure, microwave, sound and magnetism, to displace the contaminant particles in the melt towards one end, where they could be removed. The results of the Study "Manipulation of Particles by Small Forces" (see Volume II, Appendix E) were used to analyze the possibility of this glass purification method. The type of radiation selected for the analysis was visible light, because this spectral region is particularly efficient in the particle size range from 0.5 to 10 microns, where a large segment of the contaminant particle population would be found. To determine if a reasonable transport velocity could be imparted on the particle, the following equation was used:

$$v = \frac{Q_{pr} \cdot a}{\mu} \quad \left(\frac{1}{6} \frac{W}{c} \right)$$

where: v = particle drift velocity

Q_{pr} = efficiency factor for radiation pressure

a = particle radius

W = intensity of radiation

c = speed of light

μ = viscosity

The resulting velocities, assuming particle sizes from 0.5 to 10 microns, intensities of radiation from 1 to 100 watts/cm, and viscosities from 10^7 (at the melting point) to 2 at very high temperatures, were extremely low and were not considered practical. To appreciate the drastic effect of viscosity upon the drift velocity of a particle, consider that it would require approximately 8 hours to move the particles 10 cm in air. Since air is well over 1000 times less viscous than molten glass, and drift velocity is inversely proportional to the viscosity, the time that would be required to complete one purification run would have exceeded one year.

Elimination of Contamination from the Crucible. Platinum crucibles have traditionally been used in optical applications requiring high quality glass, since other metallic containers produce high contamination levels. Platinum crucibles reduce contamination but do not completely eliminate it. Contamination has been found to be largely the result of condensation of platinum oxide from the atmosphere over the molten glass.*

Even after precautions are taken to prevent this condensation, platinum traces are still found in glass that has been melted in this type of container. Although low levels of platinum contamination are not critical in the manufacture of lamps or in the major part of the refractory optical devices, they seriously degrade the life and energy levels of operation of laser glass. ** Damage to the laser glass during operation occurs because of the absorption of energy by the particles from the laser beam, the expansion of the platinum particles, and the resulting discord fracture in the glass material.

The problem of crucible contamination would be solved through levitation melting of the glass. The feasibility of being able to control the position of molten spheres of various materials, including glass, has been studied by R. T. Frost, GE Space Science Laboratory. *** There are other techniques that will compete with levitation melting to eliminate significant impurities.

*Young, C. G., and Woodcock, R. F., "Laser Induced Damage in Glass", ASTM Symposium, 20 June 1969.

**Davitt, J. "Laser Damage in Optical Glass", ASTM Symposium, 20 June 1969.

***Frost, R. T., "Investigation of the Preparation of Materials in Space", Task IV, No. DCN 1-9-54-20055, S2.

For instance, the American Optical Corporation has used high purity ceramic (mullite) crucibles to produce laser glass capable of operation at energy densities and pulse widths that would have been very improbable through the use of platinum crucibles. Although 100 percent of the crucible-related contamination cannot be eliminated using the best ceramic crucibles available thus far, it is anticipated that this type of contamination problem will be solved for great portion of glass laser applications.

On the basis of the above results, further investigation on part of the B. U. S. Study was discontinued.

III.3.5 IDEA NO. 9, MICROSPHERE REFLECTOR FOR SPECTROSCOPE AND MICRO-SPHERE SPECTROSCOPY

Goals and Objectives

Production of Spectroscope reflectors of very wide wavelength range and/or performance of high resolution spectroscopy.

Potential Users

Instrumentation Industry, Chemical and Metallurgical Laboratories.

Discussion

Transparent microspheres have the ability to absorb light having a wavelength less than the microsphere diameter and to reflect light of longer wavelength. Instrument sensitivity depends on a uniform gradation of microsphere sizes; the greater the size uniformity at any point on the reflector, the higher the instrument resolution. By processing microspheres in space, improved sphericity and/or improvements in size sorting and uniform deposition may be possible. Furthermore, the possibility of translating such spheres over relatively large distances at low speeds through the use of weak forces in zero "G", provides a conceivable high resolution spectroscopy capability.

Although potentially feasible to accomplish, no specific User or requirements were identified. Therefore further investigation as part of the B. U. S. study was discontinued.

III.3.6 IDEA NO. 10, SEMICONDUCTOR PROCESSING

Goals and Objectives

Accurately control the distribution of dopants in semiconductors by operating in zero "G".

Potential Users

Semiconductor manufacturers.

Discussion

Control of dopant distributions was considered in the diffusion or epitaxial growth steps carried out in the fabrication of silicon devices. However, from review of test data it was concluded that gravity has no significant influence on the rate of diffusion, as evidenced by comparing diffusions from the top side and the bottom of a wafer.

With respect to the vapor transport mechanism in an epitaxial reactor, gravity does have some influence on the distribution of gases in a horizontal flow system. With the high flow rates of gases past the silicon substrates, the gravity effect would not change the distribution of dopants in the silicon in any appreciable way.

No apparent technical advantage from using the space environment was determined in the study. Further investigation as part of the B. U. S. study was, thus, discontinued.

III.3.7 IDEA NO. 12, DEVELOPMENT OF HIGH STRENGTH, HIGH TEMPERATURE RESISTANT ALLOYS AND EUTECTICS

Goals and Objectives

The use of levitation melting and supercooling to obtain new alloys and eutectics with structures and physical characteristics not obtainable on earth.

Potential Users

Many potential users were identified for these materials (see Idea No. 6). For example, jet engine manufacturers, steam turbine - generator manufacturers, etc.

Discussion

The development of new alloys and eutectics with mixtures and grain structures not now available on earth would provide materials with unique properties which should be applicable to many industries. The availability of mixtures of materials of various densities which solidify with no tendency to separate into the constituent parts will allow uniform dispersion of reinforcing fibers in the material. Supercooling and rapid solidification should provide very fine grain castings or extrusions. Amorphous forms of alloys, eutectics, and pure metals may be achieved.

Some of the potential benefits of certain specific alloys and eutectic materials are shown in Idea No. 6. Other alloys and eutectic materials may have similar benefits, but more specific requirements are needed to warrant further study.

III.3.8 IDEA NO. 13, UNIFORM MIXING OF LEAD TELLURIDE

Goals and Objectives

Reduce cost by increasing yield.

Potential Users

Thermoelectric/thermionic equipment fabricators

Discussion

Gravity-induced convection and sedimentation forces during processing cause variations in lead telluride homogeneity, reducing yield of material acceptable for fabricating thermoelectric/thermionic elements to 20 and 30 percent. Purity is adequate, however. Processing of lead telluride in the absence of gravity was suggested as a means of increasing yield and thus reducing cost.

Although processing in the space environment would appear to result in increased yield, no specific User or requirements were identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.9 IDEA NO. 15, COATING OF POROUS STRUCTURES

Goals and Objectives

Uniform coating of porous structures to provide insulative, conductive or protective surface.

Potential Users

Not identified.

Discussion

Applying uniform thin conductive or protective coatings to porous structures is difficult to accomplish under gravity conditions. Except for the case of capillary size pores, gravity forces will exceed the combined surface energy forces of the coating-substrate combination, causing pooling and thin spots. Thus, coating porous structures in the absence of a gravity environment was suggested.

No specific User or requirement was identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.10 IDEA NO. 16, COATING OF OPTICAL REFLECTORS

Goals and Objectives

Improved aluminized optical reflectors through more even distribution of coating in zero "G" and minimized contaminants in hard vacuum of space.

Potential Users

Optical industry

Discussion

Aluminized optical reflectors are commonly fabricated by placing the reflector in a vacuum chamber and by ion sputtering or other techniques, depositing a thin layer of metallic aluminum on the reflector substrate.

Potential Benefits

Although some potential benefit could likely accrue by utilizing zero "G" and space vacuum, e.g., a reduction in background contaminant level, no specific User requirements were identified. Thus, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 11 IDEA NO. 17, HIGHER PURITY THERMOCOUPLE MATERIALS AND BONDS

Goals and Objectives

Improved thermocouple performance and reliability, by purification of materials and bonding in space.

Potential Users

Instrumentation and control industry

Discussion

Improved thermocouples are needed for diverse applications. For example, a silicon/germanium junction is used with the radioisotope power source operation. Tungsten/tungsten-rhenium junctions are critical for nuclear power applications.

Refining in space to increase base material purity (by levitation melting for example) and fabrication in an environment with minimal background contamination were suggested to provide improved performance and reliability.

Further review and dialogs with potential Users indicated that potential performance and reliability improvements attained by processing in the space environments are not sufficiently urgently needed for present and projected applications to warrant User effort at this time. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 12 IDEA NO. 18, SINGLE CRYSTAL LAMP FILAMENTS

Goals and Objectives

Improve the strength-temperature characteristics of tungsten filaments through zero "G" growth of crystal filaments and thus increase the life and reliability of manufactured lamps.

Potential Users

Manufacturers of high intensity lamps.

Discussion

Tungsten filaments are presently manufactured from ingots that are processed through powder metallurgy techniques. Inhomogeneities in the material and inter-granular defects inherent in the process degrade the operating life of the filaments. Melt processes made possible through levitation in zero gravity may improve the strength at the grain boundaries, but would vaporize certain trace additives that are necessary for strengthening the filament (see Section III. 3. 1, "Filament Materials for High Intensity Lamps"). A possible alternative to powder metallurgy is to process the tungsten filament material into a single crystal structure. The suggested process would involve levitation melting and controlled solidification of the tungsten to attain the desired single crystal structure. The absence of grain boundaries would make it unnecessary to introduce the aforementioned trace additives, because the pure tungsten would be sufficiently strong at high temperature operating conditions.

The difficulty in implementing this process would be in the directional solidification process. If a single crystal "ingot" were to be produced, the filament drawn from it could not be wound and then heated, without introducing a large degree of distortion. In effect, the single crystal filament would have a tendency to regain its original molecular orientation, as it was when the single crystal was formed. Theoretically, another approach would be to produce the polycrystalline filament material from tungsten ingots that had been melt-processed, and to attain the single crystal structure through directional solidification. The latter approach would be possible for a straight filament, but not for a double- or triple-wound one as is required for efficient operation in high intensity lamps. The idea is therefore rejected as being not feasible. Further investigation as part of the B. U. S Study was therefore discontinued.

III.3.13 IDEA NO. 19, IMPROVED UNIFORMITY IN POWDER METALLURGY MIX

Goals and Objectives

Increase homogeneity of refractory materials made by powder metallurgy process.

Potential Users

Not identified.

Discussion

The absence of gravity and availability of space vacuum were suggested as space properties which would permit improved particle size, shape and composition uniformity of powder metallurgy mixes. For example, the conventional method of preparing powders in an inert atmosphere results in gas-filled voids in some of the products. Further review questioned the desirability of "perfect" sphericity and uniformity of size attainable by solidification and screening in the absence of gravity. Spherical powder particles produce maximum porosity, which may be reduced by introducing smaller particles in controlled sizes and amounts. Some particles are intrinsically non-spherical because of the low cohesive force exhibited by the material. Only a minor increase in sphericity may be expected as compared to using the pseudo-zero gravity conditions obtained in a low-internal-pressure drop tower. Another point that was raised was that a very high vacuum, such as obtainable in space, may not be desirable. Thus a background gas pressure of about 10^{-5} torr (inert gas) may be acceptable provided the partial pressure of undesirable gases (such as oxygen) is held to a very low level.

Utilization of the space environment would provide the capability to control (to low levels) background gas pressure and composition during particle formation, to control the rate of thermal dissipation during particle solidification, and to obtain more homogeneous mixing of the powder constituents. Unfortunately, the economic and technical benefits as compared to conventional processing appeared marginal at best. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.14 IDEA NO. 20, SEMICONDUCTOR SOLDERING TECHNIQUES

Goals and Objectives

Improved silicon semiconductor electrical and thermal connections; possibly through "cold welding" and/or low contaminant "background".

Potential Users

Semiconductor manufacturers.

Discussion

Silicon semiconductors require reliable low resistance interfaces at electrical and thermal junctions. The upper temperatures for solder interfaces or intermediate contact material choices are limited by alloying and diffusion, both of which can cause silicon changes detrimental to semiconductor performance. Some studies of contact materials and interface resistance have been hampered by formation of a thin oxide on the silicon surfaces even after the most careful cleanup. A high vacuum environment, such as available in space, would retard or eliminate this surface oxide, while "cold welding" could alleviate temperature problem.

Although feasible, no significant economic or technical advantage is apparent from using the space environment. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 15 IDEA NO. 21, COATING IMPLANTABLE MEDICAL SENSORS

Goals and Objectives

Improve protective coating process by eliminating "G" loading, to reduce rejection rate during manufacture of implantable sensors.

Potential Users

Medical equipment industry.

Discussion

Implantable sensors must be coated with protective plastic films which are compatible with, and impervious to, body fluids. The present process techniques for applying the (initially) liquid coating have resulted in quality control problems; i. e. , rejection due to pin holes in the coating.

The integrity of the cured protective coating depends largely on surface energy properties of the coating and base materials; i. e. , how well the coating "wets" the base material. Gravity forces tend to counteract the surface tension forces and cause thinning of the resultant coating and consequently increase the probability of pin holes forming. The geometric configuration of the base material can also cause thin coatings, compounding the gravitational effect. Coating sensors in a gravity free environment thus would appear beneficial in assuring coating integrity.

Although some benefit would appear to accrue from applying protective coatings in a gravity-free environment, economic and technical gain over current methods is relatively minor. Thus, further investigation as part of the B. U. S. Study was discontinued.

III.3.16 IDEA NO. 22, IMPROVED PROPERTIES IN TRANSFORMER MATERIALS

Goals and Objectives

Develop or produce transformer materials with improved characteristics (smaller volume, increased conductivity, better electromagnetic properties).

Potential Users

Power transformer industry.

Discussion

Because of the large number of transformers produced yearly, there is high leverage in small percentage improvements in material characteristics. A 5 percent decrease in conductor volume with no decrease in performance, or an equal increase in conductivity, or similar gains in the insulator would gain significant portions of the market.

Directional electrical or thermal conductivity in transformer materials are other desirable characteristics.

For the given requirements, no match with space properties was identified. Thus, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 17 IDEA NO. 24, ULTRA-UNIFORM GRAIN PHOTOGRAPHIC EMULSIONS

Goals and Objectives

Fabricate improved photographic emulsions, through more precise deposition in zero "G".

Potential Users

Photographic film industry, laboratories.

Discussion

Improved uniformity of grain size, shape and spacing may be achievable in photographic film for precision data recording and/or manufacturing applications through deposition in zero "G". These improvements could result in greater density and higher resolution of optically recorded information.

Specific users were not identified. Consequently, further investigation as part of the B. U. S. Study was discontinued.

III.3.18 IDEA NO. 25, IMPROVED ENAMEL FILM ON COPPER WIRE

Goals and Objectives

Develop new film deposition techniques and materials for producing improved electrical insulation on copper wire.

Potential Users

Electric motor/transformer industries.

Discussion

Thinner and/or more concentric enamel films would permit a reduction in overall equipment size.

The thickness and concentricity of the applied enamel film depends largely on the combined surface energy properties of the enamel and copper wire. Gravity forces tend to counteract surface tension forces and cause distortion in the film. Applying enamel film in a gravity-free environment would thus appear beneficial in producing an improved enamel insulating film.

No specific user was identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 19 IDEA NO. 26, IMPROVED NUCLIPORE FILTER

Goals and Objectives

Reduction of pore size and increase in number of pores per unit area.

Potential Users

Medical and food processing industries.

Discussion

Nuclipore Filters are manufactured by General Electric for micro-analysis and micro-filtration applications in industry and research laboratories. The filters are fabricated from thin plastic films; uniform diameter cylindrical holes are formed in the plastic film by exposing in film to nuclear radiation, fission fragments "drilling" the holes. The number of holes is a function of the exposure time. After irradiation, the film is chemically treated to etch each hole to the desired pore diameter. A wide range of controlled pore diameters is readily achieved by this method.

The subject idea concerns the possible use of the naturally occurring high energy particles encountered in the space environment as a means of achieving smaller pore sizes with higher density spacing. Operation in the high radiation flux Van Allen belts is suggested.

The credibility of using natural space radiation in place of nuclear reactor generated radiation to improve nuclipore filters is suspect. Further, achieving small pore size is very likely controlled by the post-radiation chemical treatment and not the degree or type of radiation per se. In any case, no specific User could be identified who required improved capability. Therefore, further investigation as part of the B. U. S. Study was suspended.

III. 3. 20 IDEA NO. 27, PROSTHETIC MATERIAL FOR BONE GROWTH

Goals and Objectives

Develop a prosthetic material, biologically compatible with bone growth, for use in supporting the "knitting" of bones after surgery or fracture.

Potential Users

Medical materials suppliers, hospitals, doctors.

Discussion

Metallic, ceramic, or plastic open pore structures which also exhibit desired strength and rigidity characteristics are needed as bone growth prosthetic materials. The open pore structure is desired so that the prosthetic and new bone growth will combine to form an integrated support with ultimate removal of the prosthetic material unnecessary.

Fabrication of a foam type prosthetic material in the space environment was suggested.

Although possible to accomplish in the space environment, economic and technical benefits appear to be minor. Also, neither a specific requirement nor User was identified. Therefore, further consideration as part of the B. U. S. Study was discontinued.

III. 3. 21 IDEA NO. 28, IMPROVED MATERIALS FOR GAS TURBINE ACTUATION MECHANISMS AND SERVO COMPONENTS

Goals and Objectives

Increase reliability of large turbomachinery control systems.

Potential Users

Gas turbine industry.

Discussion

Improved materials are needed for actuation mechanisms and servo components for improving control reliability of large turbomachinery. Examples of desired material properties are improved corrosion resistance at high temperatures and in contact with a reactive environment, and increased resistance to high levels of vibration.

Review of the suggested Idea did not result in a match between the stated problems and utilization of the space environment. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.22 IDEA NO. 29, THIN FILM POLYMERIC MEMBRANES

Goals and Objectives

Deposition of very thin uniform polymeric coatings on a porous substrate to form efficient permselective membrane assemblies for water, air (gases) and biofluid purification.

Potential Users

Medical and ecology equipment industries.

Discussion

Thin film polymeric coatings on porous substrates are being used for purification of liquids and gases. Examples include biofluid purification (blood oxygenation, kidney machine), preparation of drinking water from saline or polluted sources by reverse osmosis and separation of helium from natural gas. Potential important future uses include oxygen concentration for hospital and industrial use, removal of oxygen from air to provide high nitrogen atmosphere for long term storage of produce, and removal of oxygen from sea water for undersea habitats.

The aforementioned purification processes could likely benefit materially from the use of thinner polymer coatings (since mass flow is inversely proportional to film thickness). Present methods of film deposition are not capable of producing uniform very-thin films. Since surface tension forces are significant in the film deposition process, there is some reason to expect that the absence of gravitational forces during the film deposition process may result in improved films.

Although the development and production of thinner polymeric films for use in purification processes were expected to be generally feasible, the available data on potential improvement gained by producing thin films in the absence of gravity could not support the suggested idea. Therefore, further investigation during the B. U. S. Study was suspended.

III. 3. 23 IDEA NO. 31, SILICON STEEL WITH BETTER ELECTRICAL CHARACTERISTICS

Goals and Objectives

Develop low loss transformer core steel.

Potential Users

Power transformer industry.

Discussion

Significant economic benefits can result from the development of new electrical grade power transformer core steels which exhibit low electrical losses. Conventional vacuum annealing, to control grain size, requires high pumping rates; some volatile impurities might also be eliminated during space processing.

Technical improvements resulting from the use of space vacuum are likely to be minor. Advantages of other space properties were not apparent. Thus further investigation as part of the B.U. S. Study was discontinued.

III. 3. 24 IDEA NO. 32, DEVELOPMENT AID IN PHONOCARDIOLOGY

Goals and Objectives

Improve understanding of cardiac dynamics by measurements in zero "G".

Potential Users

Medical profession.

Discussion

Phonocardiograms obtained for controlled stress conditions can be expected to be influenced to some degree by the absence of a gravity environment condition. This is due to the lack of a gravity induced hydrostatic loading. Analyses of phonocardiograms (and related indicators of cardiac activity) obtained in the absence of gravity may be significant in the future understanding and prevention of cardiac failure.

The suggested Idea appears to be basically a research oriented program and thus falls outside the B. U. S. Study guidelines. Further investigation was discontinued for this reason.

III.3.25 IDEA NO. 33, PROTECTIVE COATING ON BEARING ROLLERS

Goals and Objectives

Improve deposition techniques for applying thermal protective coatings to bearing rollers of high temperature material-fabricating equipment.

Potential Users

High temperature material fabrication equipment manufacturers.

Discussion

Bearing rollers in industrial heating and similar equipments operating at high temperatures have limited life. Typically, bearing rollers require replacement every six months because of excessive "wear."

Coating the bearing rollers in the space environment by the deposition of magnesium zirconate or similar material was suggested as a means of obtaining an improved roller protective coating and thus longer bearing life.

Although feasible to accomplish in space, the advantages of space processing appear marginal at best. Therefore further investigation as part of the B. U. S. Study was discontinued.

III. 3. 26 IDEA NO. 34, HIGH QUALITY THERMOSTATIC CONTROL

Goals and Objectives

Develop improved high temperature sodium-potassium filled thermostats.

Potential Users

Control manufacturing industry

Discussion

Sodium-potassium filled thermostats are a replacement for mercury-filled thermostats for high temperature (700 to 800^oF) control applications. Filling the thermostat, particularly the capillary portion, has been a difficult problem. Large, very clean vacuum chambers are required to produce effective evacuation and sealing.

Utilization of space vacuum is suggested as an alternative manufacturing facility.

The gain from the use of a space environment as an alternate facility for thermostat evacuation appears to be insignificant. Therefore further investigation as part of the B. U. S Study was discontinued.

III. 3. 27, IDEA NO. 35, IMPROVED DAIRY PRODUCTS

Goals and Objectives

Develop new dairy products with improved taste, texture and/or nutritional characteristics through use of mutated micro-organisms.

Potential Users

Dairy products industry.

Discussion

The taste, texture and nutritional value of processed dairy products (cheese/yogurt) depends to a large degree on the micro-organisms used in the process. Exposure of these micro-organisms to space radiation may produce mutations which will thereby result in improved products and/or increased production.

Similarly, other mutations might have application in different industries, e.g., waste processing and pharmaceuticals.

The advantage of space radiation over conventional laboratory techniques of producing mutations is questionable. Also, no specific User requirements were identified. Therefore further investigation of this Idea as part of the B. U. S. Study was discontinued.

III.3.28 IDEA NO. 36, BONE GROWTH IN ZERO GRAVITY

Goals and Objectives

Improve state of knowledge of mammalian bone growth and development.

Potential Users

Medical profession.

Discussion

Information resulting from a study of mammalian bone growth and development in the absence of gravity may be significant in the future understanding and prevention of bone disease and treatment of bone fractures. That the absence of gravity will effect the bone structure has been a manned space program medical concern (for the longer duration manned missions). Pre- and post-flight tests (of astronauts) on Gemini and Apollo flights has revealed bone calcium loss. Whether this calcium change is due to changes in the bone "growth" mechanism or is caused by other factors is not clear. Applying stress to the bone structure (as during exercising) appears to mitigate the calcium loss.

The suggested Idea appears to be basically a research oriented program and therefore falls outside the B.U.S. Study guidelines. Thus, further investigation as part of the B.U.S. Study was discontinued.

III. 3. 29 IDEA NO. 37, ACCELERATED HOUSING MATERIALS TESTING

Goals and Objectives

Utilize space solar radiation for accelerated testing of materials used externally on houses.

Potential Users

Manufacturers of housing materials products exposed to solar radiation.

Discussion

Housing materials are affected by long term exposure to the elements and many test programs are run to establish or verify resistance of products to environmental exposure. Solar radiation, either directly or in combination with other environmental parameters, can cause significant changes in materials properties such as strength or appearance.

In space, solar radiation flux levels are not mitigated by the earth's atmosphere. Thus, the effects of solar radiation may possibly be obtained on an accelerated basis.

Application of results to earth environmental conditions may be difficult to accomplish in that solar radiation is different in composition as compared to the atmosphere filtered version reaching the earth's surface. Also, no specific user requirements were identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 30 IDEA NO. 39, ZIRCONIUM CLADDING OF NUCLEAR FUEL ELEMENTS

Goals and Objectives

Production of more ductile and higher purity zirconium cladding of nuclear fuel elements, through more thorough contaminant removal.

Potential Users

Nuclear energy industry, nuclear fuel element fabricators.

Discussion

Current zirconium cladding suffers from contaminants; these include oxygen in particular, with traces of arsenic, phosphorus, and silicon. Higher purity would reduce the possibilities of fractures and other faults.

The current zirconium cladding has a relatively low cost. The improvement in space-purified zirconium does not appear to be financially significant, considering that present techniques are adequate although not optimum. Thus, effort on this Idea is discontinued.

III. 3. 31 IDEA NO. 40, SPONGE "GETTER" ALLOYS FOR NUCLEAR REACTOR GAS PRODUCTS

Goals and Objectives

To reduce the cost of manufacture of "getters" in nuclear reactors.

Potential Users

Nuclear reactor manufacturers.

Discussion

The getters referred to in this application consist of small metallic devices which absorb gaseous products in the reactor. The getters that are used presently consist of metallic chip assemblies weighing approximately 10 grams each. The relatively high cost of these assemblies is largely attributable to the cost of machining each unit.

In the suggested applications, the getter alloy would be melted, then expanded into a foam containing very small and uniform cell structure. The advantage of space are:

1. The ability to attain a very deep vacuum for the expansion of the trapped gas in the molten metal.
2. The capability of obtaining a more uniform cellular structure in a zero "G" environment, free from buoyancy and settling effects during the critical stages of gas expansion and metal solidification.

Total production of getter assemblies in the U.S. today is approximately 320,000. Each assembly costs less than one dollar. Even if the weight of each getter were reduced in half by using a sponge-like configuration, the total yield would be about 198 getters per kilogram, which represents less than \$200 per kilogram. In view of the low economic potential, further investigation was discontinued.

III.3.32 IDEA NO. 41, EVACUATION AND SEALING OF IR TUBES

Goals and Objectives

Increase the life of IR tubes by utilizing very hard internal vacuum.

Potential Users

Instrumentation industry.

Discussion

IR tubes are relatively lightweight 113 g (1/4 lb), high value (\$500 to \$1,000) devices. As part of the manufacturing process, each tube is evacuated to $1.3 \times 10^{-4} \text{ N/m}^2$ (10^{-6} torr) and sealed. During use, the internal vacuum condition gradually deteriorates to a limiting operating value of about $1.3 \times 10^{-2} \text{ N/m}^2$ (10^{-4} torr).

Utilization of space vacuum, at $1.3 \times 10^{-8} \text{ N/m}^2$ (10^{-10} torr) for example, during the evacuation and sealing process was suggested as a means of increasing tube life.

An analysis of the use of higher vacuum conditions revealed no significant gain in projected tube life. This results from the relatively rapid initial build-up of internal pressure as compared to the rate near the end of tube life, assuming essentially a constant leak rate. Therefore, with no apparent advantage offered by space processing, further investigation as part of the B.U.S. Study was discontinued.

III. 3. 33 IDEA NO. 43, CAVITATION AND SURFACE WETTING PHENOMENA

Goals and Objectives

Improve state of knowledge of cavitation and surface wetting phenomena in a liquid metal medium.

Potential Users

Power generation equipment industry.

Discussion

Cavitation and surface wetting problems have limited the application of liquid metal media in power generation equipment. Experiments can be conducted in space without the confounding influence of gravity. This can result in a improved understanding of the basic behavior of liquid metals during cavitation and surface wetting processes, leading to the future design of advanced turbomachinery.

The suggested Idea appears to be basically a research oriented program and thus falls outside the B. U. S. Study guidelines. Therefore, further investigation was discontinued.

III.3.34 IDEA NO. 44, WELDING OF SPECIAL MATERIALS; COPPER-ALUMINUM WELDING

Goals and Objectives

Obtain improved welding of difficult and dissimilar metals, particularly the joining of copper and aluminum.

Potential Users

Electrical and electronic industries, aircraft industry.

Discussion

Copper-aluminum welded junctions are plagued with a weakness developing from crystallization. The "clean" vacuum of space was expected to facilitate cold welding, so that heating and atmospheric contaminants, which were thought to initiate crystallization in the weld, would be minimized. That crystallization concept, upon further analysis by Dr. Moffatt of GE-CR&D, has proved to be erroneous. Additional difficult welding problems mentioned are titanium to superalloys and welding of cathodes to support structures in special vacuum tubes.

This Idea has been terminated because of lack of an identified specific User requirement.

III. 3. 35 IDEA NO. 47, FILAMENT STRUCTURES, METALLIC WHISKERS AND FIBERS

Goals and Objectives

Fabrication of superior metallic fibers through reduced loading and contaminants during processing.

Potential Users

High strength composites manufacturers.

Discussion

Present fabrication techniques are limited as to diameter and length of metallic fibers.

Improved properties and possibly unlimited length may be attainable by processing in the absence of gravity and by use of low contaminant space vacuum conditions. Fibers of nickel-tin-zirconium were suggested as potentially capable of being improved by fabricating in the space environment.

No specific user requirement were identified. Therefore further investigation as part of the B. U. S. Study was discontinued.

III.3.36 IDEA NO. 48, VIRAL INSECTICIDE MANUFACTURE

Goals and Objectives

Production of improved purity, high specificity insecticides by better separation techniques.

Potential Users

Insecticide industry, farmers, health agencies.

Discussion

Viral insecticides may replace persistent chemical insecticides in the next decade for protecting forests and agricultural crops. This is because the viral insecticide offers specificity without side effects. Such highly destructive insects as the tussock moth, eastern tent caterpillar, European pine sawfly and cotton bollworm are candidates for viral insecticides. Each of these insects causes \$50 to 100 million damage per year in the U.S.A. alone, in spite of the widespread use of chemical insecticides.

In relatively impure form, viral insecticides are currently available at a cost of \$45 to 50 thousand per pound. An estimated one ton of insecticide for each of the above insect pests would be required to control them in the U.S.A. Worldwide, about four tons each would be required. The annual U.S.A. market for control of the 5 insects noted above would be thus, about \$500 million, and \$2 billion, worldwide.

Until purity can be improved, licensing for widespread application probably will not be granted.

The purity problem may be solved by manufacture of the insecticide in the space environment. Electrophoresis, without gravity-imposed performance limitations, has the potential for producing higher purity viral insecticides.

Viral insecticide manufacture has been previously covered in a related Study (see Manufacturing in Space Payloads for the Space Shuttle, by L. McCreight and R. Griffin, General Electric Co.). Therefore further investigation as part of the B. U. S. Study was discontinued.

III.3.37 IDEA NO. 49, IMPROVED VACCINES

Goals and Objectives

Production of higher purity vaccines by better separation techniques.

Potential Users

Pharmaceutical industry, doctors.

Discussion

Increasing the purity of new inactivated vaccines is a major concern. The problem arises from the pathogenic properties of the whole vaccine virus and the toxicity of possible contaminants. This, plus the growing conviction that viruses play an important role in carcinogenesis has complicated the purification process. Since oncogenic properties can persist in the absence of live virus, the ultimate purification approach must result in removal of all genetic information (nucleic acids), whether derived from the vaccine virus per se or from the tissue culture and/or its possible contaminants.

As an example of the problem, some vaccine viruses needed to control serious respiratory diseases can also induce tumors. This has been shown to be due to incomplete removal of DNA from the vaccine. Electrophoresis performed in the space environment, without the gravity-induced limitations of convection and sedimentation on separation resolution, has been recommended for separating the desired vaccine proteins from the nucleic acids.

Present U.S.A. consumption of the 10 most common vaccines amounts to about 60 million doses per year. By 1990 and assuming a public health level equivalent to present day U.S.A. standards, world consumption of vaccines is estimated at 1.5 billion doses per year. Normally a gram of active ingredient contains enough vaccine for about 100,000 doses. Thus, the space processing facility must have a potential capability of producing a total (by 1990) of some 15,000 grams of a number of vaccines. At present prices, this quantity of vaccine represents a value of \$375 million.

Improved vaccines have been previously covered in a related Study (see Manufacturing in Space-Payloads for the Space Shuttle, by L. McCreight and R. Griffin, General Electric Co.). Therefore further investigation as part of the B. U. S. Study was discontinued.

III. 3. 38 IDEA NO. 50, LYOPHILIZATION (FREEZE DRYING)

Goals and Objectives

New processing method.

Potential Users

Food processing and pharmaceutical industries.

Discussion

Preservation by lyophilization involves the removal of water from materials in the frozen state. The availability of an unlimited vacuum source and low temperatures during space processing may result in advantages over terrestrial methods plus provide hyper-lyophilization if desired (for micro-organism inactivation).

Lyophilization using space properties represents a generalized Idea already reviewed in previous Studies (e. g. , see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.39 IDEA NO. 51, UNIFORM DISPERSION OF PARTICLES

Goals and Objectives

Improved material properties.

Potential Users

Metallurgical Industry.

Discussion

A conventionally prepared mixture of particles and base material will be more or less homogeneous depending on the relative density and miscibility of the two materials. Mixing techniques which take advantage of the absence of gravity may result in perfect homogeneity with consequent improved material properties.

Mixing in the absence of gravity of hard to mix or immiscible materials represents a generalized Idea already reviewed in previous Studies (e. g. , see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.40 IDEA NO. 52, FIBER REINFORCED COMPOSITE MATERIALS

Goals and Objectives

Improved materials.

Potential Users

High strength material fabricators.

Discussion

Preferential orientation and spacing of fibers (or whiskers) in the metallic substrate is necessary to achieve the maximum gain in mechanical and metallurgical properties. Special mixing techniques made possible by processing in the space environment may result in the desired fiber spacing uniformity and orientation.

Space processing of fiber-reinforced composite materials represents a generalized Idea already reviewed in previous Studies (e. g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.41 IDEA NO. 53, CEMENTED COMPOSITES

Goals and Objectives

New materials with unique properties.

Potential Users

Metallurgical industry.

Discussion

Cemented composites are those materials in which particles of high melting point are bound together in a matrix of a material with a low melting point. Processing in space may permit use of a wider range of particle and matrix density combinations without degrading the homogeneity of the resulting composite, and, thus, enable the development of new materials with unique properties.

The preparation of cemented composites in the absence of gravity represents a generalized ideal already reviewed in previous studies (e.g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B.U.S. Study was discontinued.

III.3.42 IDEA NO. 54, LIQUID DISPERSIONS - SLIP CASTING

Goals and Objectives

Uniform wall thickness in complex castings.

Potential Users

Metallurgical industry.

Discussion

Wall thickness and uniformity of conventional slip castings are limited by gravity induced effects. By processing in space, the absence of gravity coupled with the inherently high surface tension of molten metals may permit the fabrication of slip castings of uniform wall thickness and with improved metallurgical properties.

Slip casting in the absence of gravity represents a generalized idea already reviewed in previous studies (e. g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.43 IDEAL NO. 55, FREE CASTING OF METALS IN ZERO "G" ENVIRONMENT

Goals and Objectives

Eliminate physical constraints in shaping of metal castings.

Potential Users

Metallurgical industry.

Discussion

Free casting in the space environment has the potential of shaping metals in the liquid state by surface tension or by the combined action of surface tension and inertial or electric field forces. Free casting may result in the fabrication of perfect spheres and spheroids, hollow spheres and ingots with anisotropic structure for later terrestrial fabrication.

Free casting represents a generalized idea already reviewed in previous studies (e.g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.44 IDEA NO. 56, FINE GRAIN CASTINGS

Goals and Objectives

Castings with superior metallurgical properties.

Potential Users

Metallurgical industry.

Discussion

Uniform dispersion of seed particles in the melt is required to produce fine grain castings of complicated precision components. Space processing may permit one step fabrication of castings having unique anisotropic properties superior to conventional castings and at lower cost.

Fine grain castings represents a generalized idea already reviewed in previous studies (e.g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific user requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 45 IDEA NO. 58, MEMORY DEVICES BASED ON EUTECTICS

Goals and Objectives

Manufacture small, efficient magnetic cores for logic circuits in specialized applications where semiconductors cannot be used effectively.

Potential Users

Computer manufacturers.

Discussion

Although semiconductor logic devices, such as the transistor, are usually associated with electronic computers, certain specialized applications still prefer magnetic elements. An example of such application is a computer that must withstand extremely large nuclear radiation fluxes. In addition, the magnetic element is still competitive with most semiconductor elements in terms of power efficiency.

The requirement may exist for very compact magnetic logic elements with very low electrical power requirements. Magnets whose sizes range in the order of microns are not easily manufactured with current mechanical fabrication techniques. The assembly of such micromagnets into arrays for circuit integration would further complicate the problem. The conceptual solution to this manufacturing problem is the formation of rod-like eutectic structures by directional solidification of an eutectic alloy containing ferromagnetic material in one of its phases (see Discussion, Section III. 2. 1, "Growth of Eutectics with Precise Microprojections . . ."). The uniformity of shape and spacing necessary in the logic circuit application may be attainable only through directional solidification in a convectionless field, in zero gravity.

The general Idea is within the context of the B. U. S. Program, however, no specific User organization or Key Individual was able to be identified. Thus, further investigation as part of the B. U. S. Study was discontinued.

III.3.46 IDEA NO. 61, FERROELECTRIC TRANSDUCERS

Goals and Objectives

Grow superior high-stability ferroelectric transducer crystals.

Potential Users

Instrument manufacturers, transducer manufacturers

Discussion

This problem is similar to the other crystal-growing Ideas (6, 18, 45, 46, 71) in that superior crystals may be expected in a zero-gravity environment with nearly-zero vibration levels.

No potential User showed significant interest in this idea, and requirements were not defined. Discontinuation was thus, advised.

III. 3. 47 IDEA NO. 62, PRECISION SHAPING OF MIRRORS

Goals and Objectives

Precision coating or shaping of mirrors by use of an electron beam in space to add or remove material of fractional wavelength thickness.

Potential Users

Optical industry, telescope maker, microwave antennas.

Discussion

The use of an electron beam in the high vacuum of space was suggested as a precise way of shaping optical mirrors where it may be desirable to add or remove material in small quantities to achieve surface accuracies to a small fraction of a wavelength of light. Optical plating of such mirrors with aluminum coatings, free of oxygen contamination might also be accomplished in space.

The use of an electron beam as a tool for machining precise surfaces in space was suggested by a number of companies; however, no one stated the advantages of space over existing facilities.

No User was identified who could definitize his problems which reflect a need for this capability, and work on this Idea was terminated.

III.3.48 IDEA NO. 63, LEVITATION MELTING OF METAL

Goals and Objectives

Improved mechanical and metallurgical properties.

Potential Users

Metallurgical industry.

Discussion

Levitation melting and solidification appears readily accomplishable in the space environment using automatic three-axis electromagnetic positioning. Levitation melting and solidification can eliminate contamination (from a crucible), permit formation of segregation free alloys and provide a high degree of supercooling before solidification.

Levitation melting represents a generalized idea already reviewed in previous studies (e.g., see Space Processing and Manufacturing, NASA/MSFC report ME-69-1). Since no specific User requirements were identified, further investigation as part of the B. U. S Study was discontinued.

III. 3. 49 IDEA NO. 64, STRESS-FREE GLASS CASTINGS

Goals and Objectives

Development of stress-free castings for special glass applications.

Potential Users

Glass product manufacturers.

Discussion

The casting of materials in molds results in residual stresses in the final product due to differential cooling of the material in the mold. Although this can be partially alleviated by annealing or normalizing, it cannot be eliminated entirely. The residual stresses have deleterious effects when present in some assemblies where long term high stability is required.

It is possible that space manufacturing using containerless melts and forming the material by electromagnetic, electrostatic, centrifugal spinning or other techniques, may result in stress-free formed materials.

The development of stress-free castings and the forming of materials in space by forces rather than by using molds may have many benefits. Such formed materials in the molten state will cool by radiation from the surface. The temperature gradient will start nucleation of crystals at the surface of the material and the crystals will grow toward the center of the casting along radii. In cases of a high degree of supercooling prior to solidification, the solidification will occur with almost explosive rapidity. There will be little or no time for the crystal structures to grow and the result may be amorphous forms of the material or very fine polycrystalline structure. These structural forms are rarely if ever seen on earth where it is difficult to achieve a high degree of supercooling of most materials because contamination from the container provides nucleation sources which causes crystallization to begin as soon as the local surface reaches the solidification temperature and before it can supercool. This Idea was incorporated into Idea number 60.

III. 3. 50 IDEA NO. 65, SUPER THIN SAW BLADES FOR CRYSTALS

Goals and Objectives

Increase yield of crystal wafers from a boule.

Potential Users

Semiconductor fabricators.

Discussion

Currently, the saw kerf, in slicing 10 mil thick crystal wafers from a boule, is 8 mils wide. This 8 mil saw kerf is produced by a 4 mil thick steel blade encrusted with diamond particles to provide the overall 8 mil kerf. Improved diamond particle size uniformity (in smaller particle sizes), possibly attainable under zero gravity processing conditions, was expected to result in a thinner saw kerf and a consequent greater yield of crystal wafers from a given crystal.

According to commercial suppliers of this type equipment, suitable diamond particles in smaller, uniform sizes are already available. Therefore, since there is no apparent advantage to space processing, further effort as part of the B.U.S. Study was discontinued.

III.3.51 NO. 66, PARTICLE TRANSPORT IN THE VAN ALLEN BELTS

Goals and Objectives

Utilize the Van Allen Belts as a unique transportation medium.

Potential Users

No User identified.

Discussion

During discussions with potential Users, Ideas have originated which are not directly related to a particular problem area requiring solution. This type of conceptualization during our dialogs with Key Individuals was not discouraged, since it could lead to concrete ideas for which a specific use can be identified. In this vein, we accepted the following Idea, which subsequently proved to have no identifiable application or User.

For many years, geoscientists have been aware of the unique properties of the Van Allen Belts. No practical use has yet been found for these properties. Particularly intriguing, in conjunction with the objectives of the B. U. S. Study, is the possibility of using the particle transport properties of these belts. We are referring to the ability to transport sub-atomic particles through the whole extent of the belts at rates varying from a few seconds to several minutes. A spacecraft at a low point in the Van Allen Belts could activate such transport phenomenon for subsequent pick-up at another point in the belt. Unfortunately, there is not sufficient knowledge of the mechanics of this transport phenomenon or the means of controlling it. Thus, no practical use has been found, and any investigation would be purely scientific in nature.

Investigation of this Idea as part of the B. U. S. Study was not carried further.

III. 3. 52 IDEA NO. 67, X-RAY TUBE PHOSPHOR DEPOSITION

Goals and Objectives

Superior deposition process.

Potential Users

X-ray equipment.

Discussion

Phosphors represent a relatively low (10's of dollars per KG) value material, but their "pull through" value after deposition on the tube face is high (100's of dollars per KG). Consequently, utilizing space environment properties as a basis for better deposition techniques to reduce phosphor use and/or improve coating uniformity was suggested as an area for investigation.

No significant advantages to space processing were identified. Therefore further investigation as part of the B. U. S. Study was discontinued.

III.3.53 IDEA NO. 88, MUTATION AND GROWTH OF MICRO-ORGANISMS

Goals and Objectives

Determine effectiveness of space environment in producing favorable micro-organism mutations.

Potential Users

Pharmaceutical and Food Processing Industries.

Discussion

Micro-organisms are widely used in the production of pharmaceutical and food products. Specific strains are selected to maximize such factors as yield, taste, texture, appearance and composition. Mutations of these strains can be obtained by exposing the strains to a high radiation environment. Further culturing of the mutation may result in a new strain of micro-organism having the beneficial effect of increasing yield, improving taste, etc.

Exposing existing strains of micro-organisms to a radiation environment in the absence of gravity may be a more effective means of producing favorable micro-organism mutations.

The suggested Idea appears to be basically a research program and thus falls outside the B. U. S. Study guidelines. Further investigation was discontinued for this reason.

III.3.54 IDEA NO. 69, GLASS FIBERS IN LAMINATES

Goals and Objectives

Investigate glass fiber lubricants.

Potential Users

Woven glass fiber applications (tire, pressure vessel industries).

Discussion

Glass fibers are coated with a thin film of lubricating material to protect the glass fibers during the weaving process. However, discontinuities develop in the protective film. Investigating the adhesion characteristics of various protective lubricating films could be facilitated by the space environment, particularly by the low contaminant background and gravity free conditions.

The suggested Idea, not further supported by a User, appears to be a research-oriented program, and, thus, further investigation was discontinued.

III.3.55 IDEA NO. 70, SILICON IMPURITIES

Goals and Objectives

The elimination of trace contaminants in silicon crystals to improve their uniformity and electrical characteristics.

Potential Users

GE - Power & Distribution Division

GE - Space Technology Products Group

(Medical Supply Houses, Clinics, Hospital, Electrical Utility Cos., etc.)

Discussion

The removal of impurities may be achieved by float-zone refining in space environments where the absence of gravity will facilitate the use of larger float-zones and larger diameter boules without danger of the molten zone running or leaking away. The removal of impurities from silicon and the growth of large silicon crystals are related. Thus, this Idea was combined into Idea No. 46.

III.3.56 IDEA NO. 71, GALLIUM INDIUM PHOSPHIDE CRYSTAL GROWTH

Goals and Objectives

To obtain Ga InP crystals in larger quantities and at lower costs.

Potential Users

GE - Lighting Laboratory

GE - Corporate Research & Development Lab

GE - Miniature Lamp Division

Discussion

The problem is to develop a simplified technique for growing GaInP crystals in large quantities and at a reasonable cost. The absence of gravity and convection effects in the space environment should facilitate such crystal growing techniques. The material is used for solid lamp devices and in light emitting diode display devices. The potential market is rapidly increasing.

Current price of the gallium phosphide crystals is \$22/gram or approximately \$10,000 per pound. In the "Econometric Analysis of Crystal Growth in Space" performed by GE-SSL for NASA/MSFC under Contract NAS8-27942, it was estimated that the price of these gallium phosphide crystals would be reduced by two-thirds, but this will still be a selling price of approximately \$8/gram (\$3,300 per lb). The use of the gallium phosphide crystals in solid state lamps is expected to result in a 100-fold increase in the market by 1980 which will be of the order of \$40 million per year.

Because of the aforementioned related on-going Study, work on this Idea was terminated.

III.3.57 IDEA NO. 72, REMOVAL OF BORON OXIDE IMPURITIES

Goals and Objectives

Produce boron oxide of higher purity than that obtained with current techniques, for use in high intensity lamps.

Potential Users

Solid state lamp industry, typically GE Lamp Division.

Discussion

B_2O_3 is used for the encapsulation of gallium phosphide, which is used in the manufacture of solid state lamps. Although B_2O_3 produced today is extremely pure, the lamp industry requires the removal of at least 50 percent of the water impurity from this highly hydrophilic substance. The presently used method for degassing impurities is to heat the B_2O_3 to $1500^{\circ}C$ at 1.33×10^{-4} newton/meter² (10^{-6} Torr). It would be desirable to use higher temperatures and a deeper vacuum to achieve higher purity level, however, this gives rise to B_2O_3 reaction with the platinum crucible, which in turn causes more impurities. Using a ceramic crucible does not offer a solution to the platinum contamination problem, since B_2O_2 adheres to the ceramic crucible.

The proposed solution is to utilize levitation melting in a high vacuum. Since crucible effects are eliminated through levitation, a temperature suitably in excess of $1500^{\circ}C$, and a pressure less than 1.33×10^{-4} newton/meter² (10^{-6} Torr) would be used to attain the desired level of purity. In assessing the advantage of the space environment in this application, the first consideration was whether a suitable process might be developed for a 1-G environment. It has been experimentally observed that levitation melting using electromagnetic energy is more effective in substances that contain oxides than pure substances, thus, B_2O_3 might be levitated in a 1-G environment. Vacuums lower than 1.33 newton/meter² (10^{-6} Torr) are routinely obtained in laboratories, therefore, the vacuum capability of space does not present a true advantage.

B_2O_3 as presently produced costs \$1100 to \$2200 per kilogram. The world consumption of B_2O_3 is approximately 27.2 kilograms (6000 lb) per year. Thus, based on today's market the total value of this world production is approximately \$30,000 to \$60,000 per year.

In view of the probability that the higher purity that is required can be obtained in 1-G, and the low demand for B_2O_3 , this idea was removed from further consideration in the B. U. S. Study.

III.3.58 IDEA NO. 73, EMISSION SPECTROGRAPHY, PARTICULARLY FOR GLASS

Goals and Objectives

A service for identifying and analyzing impurities in glass.

Potential Users

Glass Industry.

Discussion

The glass industry can profit by developing very high purity glass. Current spectrographic techniques do not have the sensitivity and resolution desired due to contaminants in the earth-based "clean" facilities. Space provides a clean vacuum which may facilitate measurements.

This is also a service likely to have a very low volume of business. Discontinuation of effort was recommended, since improvement of non-space approaches should be attempted first.

III.3.59 IDEA NO. 74, FACILITY FOR PRECISE ALLOY FORMULATION AND ANALYSIS

Goals and Objectives

Alloy formulation and analysis service.

Potential Users

Metal Processing industry.

Discussion

A facility for the preparation of unique test specimens for later ground analysis of properties may be advantageous. For example, in the preparation of test specimens of new alloys (or other solidified mixtures) in which only trace amounts of additives are required, the user must be assured that the additives are uniformly distributed. When significant differences in the specific gravity of the additive and base material exists, processing in the absence of gravity may be of value in assuring homogeneity. As another example, space vacuum could be used to prepare test specimens free of dissolved gases, such as oxygen. The facility could also be used to obtain basic thermodynamic heat transfer data on conduction and radiation without the confounding influence of convection.

No specific User requirements were identified. Therefore further investigation as part of the B.U.S. Study was discontinued.

III.3.60 IDEAL NO. 75, THERMOGRAPHIC AND NUCLEAR SCANNING

Goals and Objectives

Utilize thermographic and nuclear scanning techniques for medical purposes, presumably increasing effectiveness in the space environment.

Potential Users

Medical field.

Discussion

The use of thermography has led to early detection of certain tumors; nuclear techniques have been utilized for such measurements as digestion process rate. The techniques are effective, and were thought to be possibly more effective with the patient in space.

No characteristics of these two scanning techniques has been shown to be better defined in a space environment. Thus the idea has been terminated.

III.3.61 IDEA NO. 76, EDGE BONDING PLASTIC SHEET

Goals and Objectives

Improve bond appearance.

Potential Users

Home furniture and appliance manufacturers.

Discussion

A current problem in the area of cabinetry of audio-electronic equipment is the edge bonding of plastic sheet without spoiling the surface finish.

Discussion of the edge bonding of plastic sheet problem did not result in an approach which would utilize the space environment. Therefore further effort as part of the B. U. S. Study was discontinued.

III. 3. 62 IDEA NO. 77, INTERRUPTOR ASSEMBLY

Goals and Objectives

To improve the operating life of vacuum interruptors used in electrical distribution and protection systems.

Potential Users

Electrical Power Transmission and Distribution Industry.

Discussion

One of the primary causes of performance loss and failures in vacuum interruptors is the degradation in vacuum. Extreme care must be exercised during the manufacturing process to ensure that the parts surfaces are clean of substances that will vaporize under arcing conditions. The integrity of the high vacuum after the sealing operation must also be ensured.

Following is a typical manufacturing sequence for an interruptor:

1. Parts cleaning
2. Parts degassing: 10^{-5} Torr., 1000°C for 2 hr
3. High temperature brazing: 950°C - 1000°C
4. Leak check of subassembly
5. Additional brazing: 740°C
6. Environmental degassing: 450°C
7. Welding of assembly
8. Exhaust (pump-out operation)
9. Pre-bakeout Hi-Pot test
10. Bake-out: 12 hr at 400°C

11. Hi-Pot test

12. Final pinch-off

The analysis indicated that an ultra high cleanliness manufacturing facility would be useful in Steps 1, 2, 6, and 10. High vacuum would be useful in Steps 1, 2, 6, 7, 8, and 10.

The role of a space facility in attaining the desired vacuum and clean-room environment was investigated. Experiments that had been conducted at the GE Power Transmission Division showed improvement in performance up to a level of vacuum from 10^{-5} to 10^{-7} Torr. The leveling off in performance within that pressure interval is interpreted as evidence that the extremely hard vacuum, attainable in space but not easily attainable on the ground (i.e., 10^{-10} to 10^{-13} Torr.), may not be advantageous. Similarly, the cleanliness requirements during critical assembly stages in manufacturing could be met through special design techniques utilizing current technology.

Because of the low likelihood that the space environment will present a significant advantage in the manufacturing process, further effort as part of the B.U.S. Study was discontinued.

III. 3. 63 IDEA NO. 78, ALLOY PREPARATION

Goals and Objectives

Obtain pure materials with characteristics approximating the theoretical properties.

Potential Users

This subject is generic rather than specific and related specific Ideas are discussed elsewhere in this report.

One suggestion originated in a meeting with Allegheny-Ludlum Steel Co. which was particularly concerned with the removal of impurities, especially oxygen.

Discussion

The determination of actual material characteristics as compared to their theoretical characteristics still show marked differences in some cases. For instance, in magnetic materials, the purer the material - the better the magnetic properties in general. It would be of special scientific interest (and with potential for practical applications) to determine the magnetic properties of metals without paramagnetic impurities.

In the purification of metal powders, the reduction of oxygen to less than 100 parts per million is desirable for some uses.

The preparation of metallic whiskers has demonstrated material properties can be achieved far above those normally associated with a particular material prepared by conventional means. Research and development effort should help explain why this is so, and how to get the superior material properties more easily.

This Idea was combined into Idea No. 74, Section III. 3. 59.

III.3.64 IDEA NO. 79, CROSSLINK OF POLYMERS BY RADIATION

Goals and Objectives

Polymer production.

Potential Users

Plastics Industry.

Discussion

Polymerization, the chemical reaction by which a polymer is formed, may be initiated by thermal, catalytic and irradiation techniques. Relatively, irradiation techniques (UV, electrons, gamma rays) are little used due to cost considerations. By carrying out the polymerization reaction in the space environment, background space radiation could be used to initiate the polymerization chemical reaction.

Background space radiation represents a wide spectrum of largely uncontrollable radiation. For a quality polymer product, close control of the irradiation source is necessary. Therefore, with no apparent advantage to space processing, further investigation as part of the B. U.S. Study was discontinued.

III.3.65 IDEA NO. 80, CRYOGENIC/SUPERCONDUCTIVITY FACILITY

Goals and Objectives

Large capacity test facility.

Potential Users

Electric Power Equipment Manufacturers.

Discussion

Superconductivity research (conductors, magnets) requires working at liquid helium temperatures (10°K). Large capacity facilities would incur high costs. By using space as a thermal sink, the required low temperatures may possibly be obtained by use of a space radiator or by directly exposing the superconductor to space. Lack of specific Users and requirements caused this Idea to be dropped.

III.3.66 IDEA NO. 81, IMPROVED MAGNETIC MATERIALS

Goals and Objectives

Obtain theoretical performance.

Potential Users

Electronic Components Manufacturers, Ferrous Material Handling Equipment Manufacturers.

Discussion

Magnetic materials, such as Alnico 9, are widely used. However, conventional processing methods result in a material having magnetic properties far less than the theoretical potential. Pre-solidification processing in the absence of gravity may result in optimum shaping and orientation of particles within the magnetic material and thereby improve magnetic performance. No specific User requirements were identified; therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.67 IDEA NO. 82, COPPER DEPOSITION ON SUBSTRATE

Goals and Objectives

Alternate process with more uniform, purer product.

Potential Users

No User identified.

Discussion

Electrolytic deposition of copper on various substrates is a well known and extensively used process. Because of this extensive use, investigation of an alternate method of copper deposition utilizing space environment properties was suggested.

Since no specific User or requirements were identified, further investigation as part of the B. U. S. Study was discontinued.

III.3.68 IDEA NO. 83, GLASS AND CERAMIC-TO-METAL SEALS

Goals and Objectives

Improve seal reliability.

Potential Users

Electrical Equipment Industry.

Discussion

Glass and ceramic to metal seals are used for electrical connections in such diverse applications as capacitors, pressurized water reactors, transformers, and batteries. To obtain a gas/liquid tight interface between the glass or ceramic insulator and metal mounting structure, an oxide free metal surface is required. As an alternate to present fabrication methods, fabrication in space, using space vacuum to maintain the oxide free condition in combination with the absence of gravity for better solder flow, was suggested as a possible means of attaining improved seal reliability.

Seal reliability is already high; thus, the potential advantage of space processing over conventional techniques does not appear to be significant. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.69 IDEA NO. 85, ULTRA-FINE WIRE

Goals and Objectives

Production of a very small diameter wire.

Potential Users

Electronic Components Industry.

Discussion

Wire is commercially produced in a wide range of sizes, ranging down to less than 0.0254 mm (0.001 inch) in diameter for the bare wire. For example, 0.0175 mm (0.0007 inch) diameter nickel wire is used in semiconductors. In small quantities, wire has been produced in even smaller diameters. Using the composite wire drawing process, platinum wire of 0.000825 mm (0.000033 inch) diameter has been fabricated. Since small diameter wire represents a high value product on a weight basis, fabrication in space was suggested.

No specific User requirements were identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III.3.70 IDEA NO. 86, MEDICAL TECHNIQUES

Goals and Objectives

Utilize properties of the space environment to achieve better medical performance in several areas.

Potential Users

Medical Profession.

Discussion

A number of possible areas for improvement of performance in the medical profession have been suggested:

1. Information on fluid balance, cardiovascular function, and calcium metabolism for various diseases.
2. Basic information on effects of drugs on cells.
3. Baseline information on nutrients and caloric intake for various work loads.
4. Development of unique surgical and therapeutic procedures, especially where the decreased hydrostatic load and the elimination of musculo-skeletal loads may be critical to the process.
5. Other related medical Ideas included in other Ideas may be associated with above.

Since no specific User requirement to take advantage of space properties has been identified, the idea has been terminated for this Study.

III.3.71 IDEA NO. 87, SMALL SPHERE - GROSS ATOMIZATION

Goals and Objectives

Spherical particles for specialized application.

Potential Users

No User Identification.

Discussion

The sphericity of solid particles produced on earth by atomization are slightly irregular due to gravitational induced influences during processing. Processing in space in the absence of gravity has the potential for producing essentially perfect spherical particles. Perfect sphericity can also be coupled with potential improvements in sorting with gravitational influences removed plus improved purity resulting from the very low contaminant background.

No specific User requirements were identified. Therefore, further investigation as part of the B. U. S. Study was discontinued.

III. 3. 72 IDEA NO. 88, NUCLEAR REACTOR MATERIALS

Goals and Objectives

The objective is to obtain nuclear reactor materials with more uniform dispersion of components.

Potential Users

GE-Reactor Fuels and Reprocessing Dept.

GE-Materials and Processes Technology Laboratory

Discussion

The development of techniques to obtain uniform metallurgical powders with selected particle sizes, shapes, and uniformity of composition may be possible in space in the absence of gravitational effects. Uniform powder particles may be processed in the zero gravity and high vacuum environment of space without a tendency to separate due to variations in density of the particles mixed.

For nuclear reactor materials, refractory metals are required. Nuclear fuel elements are clad in zirconium. The ductility of the zirconium cladding is important as any structural faults or dislocations result in leakage of the radioactive fuels. High vacuum (especially extremely low partial pressure of oxygen) is an advantage in obtaining zirconium with minimal oxidation which would otherwise reduce its ductility. Contamination by arsenic, phosphorus, or silicon traces are also detrimental.

The relationship of this Idea to others in the Study led to its incorporation in Idea No. 39 (see Section III. 3. 30) and No. 42 (see Section III. 1. 6).

III.3.73 IDEA NO. 91, CALIBRATION OF TEST EQUIPMENT

Goals and Objectives

Calibration of primary and secondary instrument standards.

Potential Users

National Bureau of Standards and Industry.

Discussion

The space environment offers a unique potential for the calibration of selected primary and secondary standards. The absence of gravity-induced forces, the need for vacuum conditions, long path lengths (spacecraft to earth or moon), etc., may improve calibration accuracy and/or range. Instrument examples are radiometers, infrared detectors, gravity meters, magnetometers and seismic sensors.

No specific User was identified. Therefore further effort as part of the B. U. S. Study was discontinued.

III.3.74 IDEA NO. 93, CERAMICS AND REFRACTORY MATERIALS

Objectives

The objective is to obtain new ceramics and fusion cast refractories.

Potential Users

Corning Glass personnel suggested this Idea; however, they were unable to expand on the Idea at this time.

Discussion

Fusion cast refractories are used especially in the glass and steel industries where large furnaces and heating equipment is necessary. The fusion cast refractories offer excellent resistance to the corrosion and erosion of glass and steel furnaces. Their chemical durability can be attributed to the large crystal size, tight crystal bond, interlocking crystals, high density, low permeability, and porosity. Their chemical and physical properties are related to their microstructure, which can be greatly varied by controlling the composition, dissolved gases, degree of superheat, and the rate of cooling and setting of the molten material.

One of the major problems in fusion casting is the tendency of the ingot components to segregate due to gravity. This upsets the crystal pattern and promotes variations in the resistance or wear characteristics and the thermal properties of the refractory materials. Crystallization of $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot \text{ZrO}_2$, $\text{MgO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Cr}_2\text{O}_3$, $\text{Al}_2\text{O}_3 \cdot \text{CaO} \cdot \text{Na}_2\text{O} \cdot \text{CaF}$ under conditions of zero gravity would promote the production of uniform refractory ingots. Uniform ingots with uniform resistance characteristics would result in refractories with longer useful (i. e., more heat per furnace) life.

Potential Benefits

Corning estimates that a 10 percent increase in the life of fusion cast refractories would save the Users approximately \$44.8 million/year; however, the cost of refractories and their

weight make them a poor candidate for space manufacture. The market potential indicates that space developments which would be applicable to production on earth would certainly be justified by the potential dollar return.

This Idea was partially incorporated into Idea No. 8 (see Section III.3.4), and Idea No. 60 (see Section III.1.9).

III.3.75 IDEA NO. 94, METAL PURIFICATION

Goals and Objectives

The objective is to develop techniques for obtaining metals with less contaminants.

Potential Users

Several companies suggested the need for obtaining purer metals for various purposes including General Electric, Kaiser Aluminum, Allegheny Ludlum, Foote Mineral, etc.

Discussion

The levitation melting of refractory metals without a container will aid in the preparation of pure metals. The containerless melt can be zone refined and/or superheated to drive off some impurities. Solidification while floating in zero G in a high vacuum, should eliminate subsequent contamination.

Ultra-clean surfaces and high vacuum may contribute to improved mechanical junctions for pure metals.

Allegheny Ludlum is interested in pure metals, particularly magnetic materials, and silicon steels which they provide to GE for motor and generator laminates.

The GE Metallurgical Products Department is interested in higher purity tungsten-tungsten rhenium materials for thermocouples.

This Idea is essentially covered in many of the ideas in the study.

III. 3. 76 IDEA NO. 99, MASS SPECTROMETRY IN SPACE

Goals and Objectives

Improve sensitivity of analysis.

Potential Users

No User was identified.

Discussion

The theoretical sensitivity of mass spectrometers is limited by the background atmosphere within the mass spectrometer analyzer section. Although background effects are minimized by effective pump-down operating procedures, using a high performance vacuum pump and bake-out cycle, the utilization of the high pumping rates and low reference pressure of space vacuum should materially improve the sensitivity.

Reviews of mass spectrometry in space did not generate any specific User requirements, although the review did indicate a probable future need. This Idea was, therefore, dropped for the present Study.

III. 3.77 IDEA NO. 100, HIGH PURITY RARE EARTHS

Goals and Objectives

Improve purity of such materials.

Potential Users

Metallurgical and electronic components industries.

Discussion

Rare earth elements are used in many applications; for example, to improve the mechanical and metallurgical properties of ferrous and non-ferrous alloys, to improve the properties of catalysts and fungicides, in the manufacture of glass and refractories and to improve the properties of ferromagnets and semiconductors. The rare earth elements, Atomic Numbers 57 through 71, are nominally available in the 98 to 99 percent purity range. In some applications, particularly the electronic components area, a higher degree of purity can be expected to result in increased performance. Thus, processing in space,utilizing space vacuum and the absence of gravity (containerless levitation melting and contaminate removal) would appear to offer technical and economical benefits.

A review of the High Purity Rare Earths area did not yield any specific User requirements. The Idea was, therefore, not considered further. However, the increasing application of rare earths to improving electronic type components indicates a potential future need.

III.4 INTEGRATED TIME PHASING

The basis for this analysis was the desired time phasing of knowledge and capabilities needed by each User organization, as expressed by Key Individuals during dialogs with the Core Team. The assessment of those timing requirements was performed as part of Subtask 1.1, "Initial Identification of Problems to be Solved" and Subtask 1.4.5 "Assessment of Timing Requirements for Settling Issues, Providing Needs, and Solving Problems". In most cases, the need for knowledge or capabilities could not be associated with a specific milestone date or time interval in the future; instead it was learned that the knowledge or capability could be used effectively in the present, in other words, "as soon as possible." A notable exception is Idea No. 42, "Precise Separation of Radioisotopes", in which the ample supply of unrefined plutonium needed to make this a practical mass processing technique will not be available until the mid-'80's, as a by-product of the highly enriched uranium reactors of that era. A few required developments were less specific, but similarly time dependent, e.g., the greatly expanded demand for large diameter silicon wafers for electrical power applications, potentially able to be satisfied through processing of large crystals in space (Idea No. 45). That demand will reach its peak when superconductor and cryogenic techniques have made underground transmission of high voltage direct current (HVDC) technically and economically feasible for wide-spread usage. In cases such as this, where the time phasing of activities is dependent, on the availability of a technological development of uncertain schedule, the time phasing used in the Study was based on an optimistic schedule for availability of the aforementioned technological development.

The results of Subtask 2.3, "Analyze Planned Future Programs for Specific Properties Which Will Provide the Required Knowledge/Capabilities", was an input to the integrated time phasing. Direction was given to the contractor by NASA not to use a rigid NASA flight schedule as a baseline for this analysis. This is discussed in Section III.1 of Volume I, dealing with the relationship of this Study to future space program plans.

Using as a guideline the availability schedule of the Space Shuttle, it was possible to identify those development steps requiring space flight using other space transportation systems. With the exception of Idea No. 38, "Safe Disposal of Radioactive Wastes", and Idea No. 96,

"Utilization of Biorhythms", all space experiments could be performed in low earth orbit (e.g., 250 to 500 km). Zero-G experiments or experimental phases required earlier than the date of availability of the Space Shuttle were categorized as candidates for flight on automated spacecraft, sounding rockets, or aircraft zero-G tests. The criteria for this categorization considered the maximum attainable zero-G time interval and the approximate size and weight limitations of spacecraft, sounding rockets and aircraft. Under very specialized conditions, preliminary feasibility tests for some applications will be able to be conducted using drop towers. The result of the Task 2 analysis with respect to time phasing of activities is documented in Section III, Volume II, under the individual write-up for each Idea.

The integrated time phasing of activities, both space and ground-based, are summarized in Figure III-34. The overall time span for each category of activity is represented by the horizontal bars on the graph. The following paragraphs describe the salient features of the results depicted in Figure III-34.

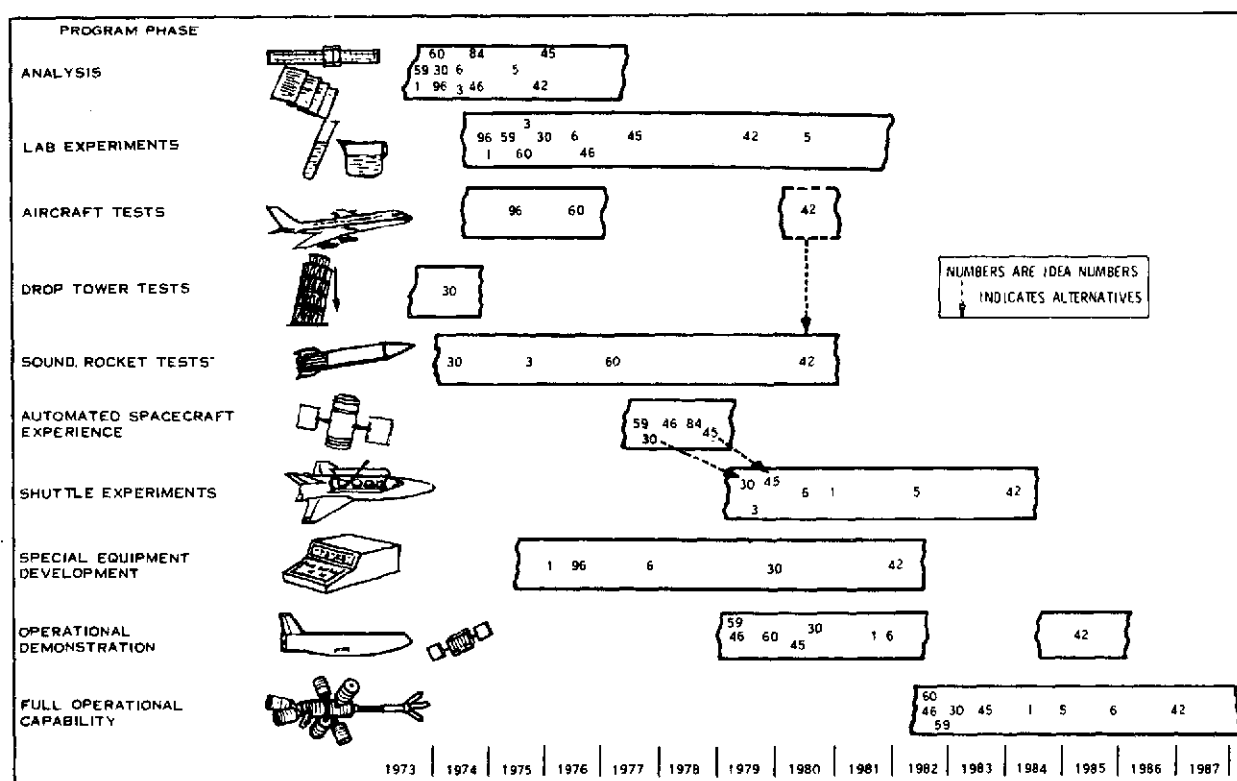


Figure III-34. Integrated Time Phasing of Space Experiments/Activities

III.4.1 ANALYSES

This phase encompasses all preliminary investigations of a non-experimental nature. Covering the period from 1973 to beyond 1976, the analyses will relate to the analytical investigations of the disciplines and phenomena involved in pertinent Ideas planning of the developmental program, trade-off of experimental alternatives, technical and economic feasibility Studies, and design of laboratory experiments. Analyses will benefit by the knowledge gained through concurrent experimental activities in other application areas. For instance, the information obtained in ground-lab experiments on epitaxial garnet-crystal growth and the processing of amorphous glass (Ideas No. 59 and 60) may benefit the analyses related to crystal growth for Ideas No. 45 and 46.

III.4.2 LABORATORY EXPERIMENTS

It can be seen that the duration of this phase is as long as the period of space experimentation; this is consistent with the Study philosophy that only the functions that cannot be performed effectively on earth are scheduled to be performed in space. Invariably, the overall experiment will require a comparison between the product of the process in a terrestrial environment versus that in the space environment, to help determine if the result obtained through space is better, and if so, how much better.

III.4.3 ZERO-G TESTS IN AIRCRAFT, DROP TOWERS, AND SOUNDING ROCKETS

Before committing to a spacecraft test, some applications will require testing in other vehicles capable of providing a limited time in zero gravity. Typical candidates for aircraft tests capable of Keplerian trajectory are "Amorphous Glass," (Idea No. 60) and "Precise Separation of Radioisotopes" (Idea No. 42).

Drop tower tests are constrained to less than 10 seconds of weightlessness; therefore, usage of this technique has limited application in development testing of Ideas identified in the B. U. S. Program. By contrast, sounding rocket tests provide 6 to 10 minutes of weightlessness, and could be used very effectively in early phases of the experiments. Three application Ideas

have been identified as candidates for sounding rocket tests: "High Purity Tungsten X-Ray Targets" (Idea No. 30), "Thermal Conductivity of Liquids" (Idea No. 84), and "Precise Separation of Radioisotopes" (Idea No. 42). However, it is anticipated that the analysis and laboratory experiment phases will identify additional sounding rocket tests in other application areas during the interim period prior to manned experimental capability in the Space Shuttle.

III.4.4 SPACE EXPERIMENTS

Many of the experimental activities are of such a nature that they require manned intervention. Because of the unpredictability of the outcome of each experimental step and of the best choice of subsequent experiment activities, automation (or remote manning) of the experiments would involve high complexity, relatively high cost, and long lead-times for development. However, the analysis identified several experiments in which the activities would be able to be conducted in automated spacecraft. These experiments are related to "Magnetic Bubble Memory" (Idea No. 59), "Silicon Crystal Growth for Power and Medical Applications" (Idea No. 46), and "Thermal Conductivity of Liquids" (Idea No. 84). Detailed tradeoffs are needed for experiments related to "High Purity Tungsten Target" (Idea No. 30) and "Large Ge Crystal Growth for γ -Ray Camera" (Idea No. 45), in order to determine whether the added experimental complexity in an automated spacecraft is justified in terms of being able to obtain the information one or two years earlier than the operational date of the Space Shuttle.

Ideally, all the identified experiments in low earth orbit should be performed in a common facility within the Space Shuttle. This would afford efficient utilization of space, equipment and man-involvement. Experiments requiring continuous periods of exposure to space environment, exceeding the orbital stay capability of the Space Shuttle, can be deployed in a detachable module that stays in orbit until the next Space Shuttle arrives to restore full experimental support. An example of an experiment requiring this capability may be in "Utilization of Biorhythms in Therapy" (Idea No. 96).

III.4.5 OPERATIONAL PHASES

Operational demonstration is required in most application areas, before commitment to full scale production or service in space. The period of performance of this phase will commence in 1979 and continue beyond 1985.

Full operational capability is envisioned as early as 1982 for the manufacture of epitaxial garnet crystals. This activity would require an automated spacecraft until the Space Shuttle becomes operationally available. Large scale, continuous production of certain products such as turbine blades (Idea No. 6) and refined radioisotopes (Idea No. 42) may require separate manufacturing facilities which are designed specifically for that purpose. Large utility demands of these processes from the space carrier, and the desirability of ample maintenance capabilities makes these large scale applications good candidates for separate facilities.

III.5 COMMONALITY ANALYSIS

For the 12 Ideas identified for continuing Study, an analysis was made of significant factors associated with their goals, critical issues, needs, problem areas, required knowledge/capabilities, programs for accruing knowledge/capabilities, and timing. The intent of such an analysis was to determine whether these Ideas possessed some common set of factors which implied a particular suitability to development or production in space.

Although while far from universally present in the 12 Ideas, there are several items of commonality that represent the majority of these Ideas.

Further commonality analysis was made at a more definitive level, that is, at the requirements level. Here, the intent was to determine whether, within the limited data available from Tasks 2 and 3, we could define commonalities in the requirements of individual space experiments, rests and operations that would indicate the possibilities of providing developmental support to more than one Idea with "commonized" missions.

Consideration was given to the identified requirements of the Users; however, an attempt was made to establish common factors which could be combined in a program, where such combination would not violate the needs of the specific users. Only limited feedback of common factors through the Key Individuals was accomplished because of the time limitations on the Study and the late inputs in many areas; however, it is felt that some valid and practicable commonalities were identified.

III.5.1 COMMONALITIES IN GOALS, OBJECTIVES, ISSUES, NEEDS, PROBLEM AREAS, KNOWLEDGE/CAPABILITY REQUIREMENTS AND TIMING

A tabulation of the factors involved in the overall identifying features of each of the 12 Continuing Ideas is given in Figure III-35.

Based on that tabulation, we have identified those factors which appear to be common to most of these Ideas. Although the 12 Ideas are likely to be a very small sample of those

POTENTIAL COMMONALITY FACTORS	CONTINUOUS STUDY IDEAS														MAJOR COMMONALITIES
	1. IMPRINTING CIRCUITRY ON CRYSTALS FOR SURFACE ACOUSTIC WAVE COMPONENTS	2. PARTICLE MANIPULATION BY SMALL FORCES	3. VIBRATION TESTING OF SMALL MOTORS	4. SINGLE CRYSTAL AND ELECTRIC HIGH TEMP. TURBINE BUCKETS	5. HIGH PURITY TUNGSTEN X-RAY TARGETS	6. PRECISE SEPARATION OF RADIOISOTOPES	7. SILICON CRYSTAL GROWTH	8. EPITAXIAL GROWTH OF CRYSTAL BUBBLE SINGLE AND GARNET FILMS	9. AMORPHOUS GLASSES AND REFRACTORIES	10. THERMAL CONDUCTIVITY OF LIQUIDS	11. SEPARATION OF BIOPOLYMERS	12. UTILIZATION OF BIOPOLYMERS			
<u>GOALS AND OBJECTIVES</u>															
PRODUCT	✓			✓	✓	✓	✓	✓					X		
PROCESS		✓											X		
SERVICE			✓												
SPACE ROLE IS		✓	✓												
DEVELOPMENT															
SPACE ROLE IS	✓			✓	✓	✓	✓	✓					X		
PRODUCTION	✓			✓	✓	✓	✓	✓					X		
IMPROVED PRECISION OR				✓											
QUALITY IN PROCESSING			✓						✓						
IMPROVED PRECISION IN															
ACQUIRED KNOWLEDGE		✓						✓							
NEW CAPABILITY											✓				
NEW KNOWLEDGE															
<u>ISSUES, NEEDS, PROBLEM AREAS</u>															
<u>GRAVITY EFFECTS -</u>															
LOADING			✓	✓		✓							X		
MASKING OF OTHER FORCES		✓											X		
CONTAINERLESS PROCESSING			✓	✓									X		
CONVECTION			✓	✓									X		
LOCAL DESATURATION			✓	✓					✓				X		
SEDIMENTATION		✓	✓	✓									X		
BUOYANCY		✓	✓	✓									X		
<u>ELIMINATION OF VIBRATION -</u>															
SEISMIC	✓		✓										X		
ACOUSTIC			✓						✓						
<u>CONTAMINATION CONTROL</u>															
ENVIRONMENTAL	✓														
PROCESS					✓	✓	✓	✓					X		
<u>OTHER TERRESTRIAL DISTURBANCES</u>											✓				
<u>KNOWLEDGE/CAPABILITY REQUIREMENTS</u>															
LONG TERM ZERO "G" FACILITY		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
MANNED PROCESSING EQUIPMENT		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
AUTOMATED PROCESSING EQUIPMENT		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
LONG TERM VIBRATION-FREE FACILITY	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
ULTRACLEAN FACILITY/ EQUIPMENT,		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
ENVIRONMENT				✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
CONTAINERLESS MATERIAL CONTROL				✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
PROCESS WASTE REMOVAL				✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
HIGH VOLUME DATA ACQUISITION				✓	✓	✓	✓	✓	✓	✓	✓	✓	X		
<u>TIMING OF DEVELOPMENT PROGRAM</u>															
ASAP	✓	✓						✓	✓	✓	✓	✓	X		
USER DEFINED END DATE															

Figure III-35. Commonalities in Goals, Objectives, Issues, Needs, Problem Areas, Knowledge/Capabilities and Timing

which eventually will be candidates for space development or production, for the present, the most common factors provide clues as to what to look for in seeking additional candidate Ideas.

Thus, Figure III-36 notes the following as factors most common to the listed Ideas:

1. Products. A large majority of the Ideas concern products rather than processes or services.
2. Produced in Space. The main emphasis of Users appears to be to utilize the space facilities for production rather than for developmental efforts.
3. Improved Precision or Quality in Processing. Users overwhelmingly are seeking improvements in processing rather than new or better information or new products. It is very likely that the low emphasis on "new" results stems from the difficulty in generating Ideas for items not somehow related to already existing items.
4. The Problem Area of Convective Effects. Gravity-induced problems appear to be the major inhibitor for most Users, with convection the major subproblem. More familiarity with other space properties may well eventually increase the consideration of such areas of vibration and contamination control.
5. Requirement for Long Term Zero "G" Facility. Based on the widely identified aforementioned problem area, this requirement is obvious.
6. Requirement for Automated Processing Equipment. The Users, oriented toward production, have, thus, carried that orientation to its logical end.
7. Implementation As Soon As Possible. Almost all Users see early needs for their items, and thus indicate early initiation of developments.

III. 5.2 COMMONALITIES IN SPACE EXPERIMENTS/ACTIVITIES

The continuing Ideas were first analyzed to determine the requirements imposed by the space experiments, tests and operations needed to implement each Idea, as shown in Figures II-12 and II-13. These requirements establish the impact of each Idea on the spacecraft and its subsystems, the orbits required, the operational procedures involved, the process and support equipments needed, and the particular space environments which would be utilized in performing the activities required to satisfy that particular concept.

Figure III-36 summarizes this step in the compilation of requirements for selected Ideas in the Study.

Analysis of Figure III-36 leads to identification of commonalities in a number of requirements:

1. Flight Parameters. Except for Idea No. 96, Utilization of Biorhythms, all experiments, tests, and other space activities, for all Ideas, exhibit no preference in orbit inclination or altitude.

Flight durations vary from seconds and minutes to days and weeks -- generally as development activities vary from simple experiments for data acquisition to full scale operations. Commonalities in flight duration thus appear to be seconds to minutes for some simple data acquisition experiments, hours to days for verification and development tests, days for pilot plant demonstrations, and days to weeks for full scale operations.

2. Special Environments. Low vibration appears to be common to all phases of experiments/activities for most of the Ideas, either as a major or minor requirement. Ultra-low "G" and isolation from other environments represent special cases for two Ideas.
3. Sensitivities. As expected from the aforementioned, protection of sensitivity to vibration is common to all phases of most Ideas. In-orbit "G" is a sensitivity of many Ideas, particularly in data acquisition, pilot plant, and full operations. The degree of that sensitivity, and whether rigorous control of crew movements and stabilization forces will be required must be eventually determined. Many cases of sensitivity to contamination appear, as do sensitivities to electromagnetic fields and ionizing radiation.
4. Shelf Life. Only two Ideas exhibit shelf life problems: Idea No. 89, Separation of Isoenzymes, and Idea No. 96, Utilization of Biorhythms.
5. Waste/By-products Removal. Removal of waste heat appears a common requirement of several Ideas in development, pilot plant, and full scale activities. Other waste/by-product requirements are shared by a few cases.
6. Major Process Equipment. Although some processing equipments are unique, potential multiple use appears possible for Vibration Isolators and Controls (Ideas No. 1 and 5). Force Generators (Ideas No. 3, 42, 89), Crystal Growing Apparatus (Ideas No. 6, 46, 59), Levitation Control Equipment (Ideas No. 6, 30, 60), Furnace (Ideas No. 6, 46, 59). Local Heating Equipment (Ideas No. 3, 30). Electrophoretic Separator (Ideas No. 3, 89), and Electron Beam Gun (Ideas No. 1, 3).

[illegible]

KEY
 ✓✓ MAJOR REQUIREMENT
 ✓ MINOR REQUIREMENT
 ○ NO REQUIREMENT AT THIS TIME
 — NOT APPLICABLE

Figure III-36. Tentative Commonality Analysis of Space Experiments/Activities (Sheet 2 of 4)

FOLDOUT FRAME /

FOLDOUT FRAME 2

Figure III-36. Tentative Commonality Analysis
of Space Experiments/Activities (Sheet 3 of 4)

7. Major On-Board Support Equipment. Support Equipment is the most likely in which a high degree of commonality will occur. Large amounts of electric power are required in 5 of the 12 Ideas, mainly in the later development, pilot plant, and full scale operations. Thermal control and spacecraft stabilization are major requirements for most phases of many Ideas. Data recording is almost a universal requirement for data acquisition, development, and verification phases. Contamination control and cooling equipment appear necessary to several Ideas.
8. Potential Degree of Automation. Most of the Ideas listed appear to require a high degree of automation as development phases reach full scale operations, while automation appears less possible in most data acquisition and verification testing phases.
9. Raw Materials. Raw materials are unique for each Idea, although quantities vary from grams (usually in early tests) up to 1000's of KG (in full-scale operations).
10. Data and Product Return. With few exceptions, most Ideas call for telemetry of phenomena and performance measurements, at least in early phases. All product Ideas call for physical return of products in full-scale operations, pilot plant demonstrations, and verification tests.

III.5.3 PRELIMINARY ESTIMATES OF CANDIDATE COMBINED MISSIONS

The tentative definitions of commonalities provide little basis for establishing a solid plan for combining experiments/activities of the listed Ideas. Preliminary combinations, however, are given as a guide to where to begin searching for such combinations.

Candidate experiments/activities for combined missions were identified mainly on the basis of special environments, sensitivities and potential sharing of major equipments.

Several tests listed for Ideas No. 1, 3, 5 and 84 requires a high degree of vibration isolation in the spacecraft and these might be flown together on one flight; tests for Idea No. 5, however, include vibration testing in the spacecraft, and this might require that they be either flown on a separate mission or performed at a different time if flown on the same mission as the other three. Combining vibration-limited tests in a single flight frees other flights from that difficult constraint, but may require a rather large vibration-free test area.

Electrical power requirements are relatively high for phases of Ideas No. 6, 30, 46, 59 and 60. Although this should not be a major problem during early development, and, possibly even

during pilot plant proof testing flights, it may become a major factor in production flights later. The major power requirement for activities in each of these Ideas is for heating the materials. Such heating activities might be performed more efficiently in space if a solar collector and focusing apparatus were developed to provide high energy heat source rather than the use of electrical heating, where the inefficiencies of generating electricity and turning it into heat becomes prohibitive for high heating capacities.

Similarly, these same five Ideas require ovens or furnaces, and such commonality of equipment may make their combined flight practicable. The problem of cross-contamination between tests, however, must be analyzed as a possible disadvantage. Such determinations are tentative based on the degree of definition of these concepts available at this time, but the possibility should be explored with the Key Users as the experiment/activities are further defined.

Sensitivity to contamination is common, to some degree, to Ideas No. 1, 6, 30, 42, 46, 59, 60, 89, and 96. Contamination control generally requires isolated facilities. The verification tests, pilot plant demonstrations, and full operations for these Ideas may well call for segregation rather than combination due to this requirement. At a minimum, the two biological Ideas (No. 89 and 96) should likely be separated. The others must be investigated for specific contaminants and the potential of contaminant control before assembling specific combinations for flight.

The similarity of orbit "G" requirements, sensitivities and certain common major process equipment (lasers) indicate the possibility of combining the verification tests of Idea No. 3 (Particle Manipulation by Small Forces) with the development tests of Idea No. 42 (Precise Separation of Radioisotopes). The operational and hardware savings of such integration will have to be evaluated against their combined test duration in the limited shuttle mission duration.

Development tests for Idea No. 96, (Utilization of Biorhythm) with their moderate to high potential for automation and minor sensitivities are candidates for combination with almost any other experiments, and thus provide the advantage of flexibility in scheduling.

In summary, it appears that, although most space experiments/activities for the Identified Continuing Ideas exhibit some uniqueness, logical groupings for combined missions are very likely to be found. Such groupings, and multiple use of costly equipment can result in operational and hardware cost savings. On the other hand, there will also be requirements for more definitive analyses, and possibly some experiments to determine the possibilities of cross-contamination and detrimental interaction among such combinations.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

IV.1 CONCLUSIONS

Section I.3, "Significant Points in the Technical Report", discusses a number of general conclusions we have drawn as a result of the Phase I study. We will summarize these conclusions first, and follow with a number of specifics.

IV.1.1 GENERAL CONCLUSIONS

The following tabulation of general conclusions on the study is amplified in Section I.3.

1. The dialog technique, a major point in our approach, works.
2. We gained the support of a representative sample of non-aerospace organizations.
3. Selected types of companies can and will, with sufficient time, "bridge the gap" between their areas' needs and space capabilities.
4. The 6 to 7 year wait for Shuttle is not considered by many potential Users to be too far off to warrant active study and planning now.
5. Commercial industry concern over the business aspects of their potential space involvement is as intense as over the technical.
6. The potential benefits, for only the four study areas, small sample of industry, and conservative assumptions, are, typically, in the billions of dollars and thousands of lives saved.
7. The rudimentary nature of technical analysis on many of the Ideas makes it imperative that further in-depth effort be applied before such Ideas can be considered feasible.

IV.1.2 SPECIFIC CONCLUSIONS

A measure of the success of a study such as this is the degree to which the results meet the objectives and other aims established for the study. Figure IV-1 makes such a step-by-step comparison and draws conclusions from each step.

AIMS	RESULTS	CONCLUSIONS
<p>THEME (FIGURE I-1)</p> <p>...PRODUCTS, PROCESSES, SERVICES...DEVELOPED OR PRODUCED IN...SPACECRAFT...USED DIRECTLY ON EARTH."</p> <p>OBJECTIVES (FIGURE I-2)</p> <p>..."SPECIFIC USERS"</p> <p>..."SPECIFIC KNOWLEDGE OR CAPABILITIES"</p> <p>"CORRELATE KNOWLEDGE/CAPABILITIES WITH USERS"</p> <p>...POTENTIAL BENEFITS"</p> <p>INTENT (FIGURE I-4)</p> <p>...EXPERIMENT IN SOPHISTICATED MARKETING"</p> <p>...INITIATIVES IN PRIVATE COMPANIES"</p> <p>...GOOD INFORMATION EXCHANGE BETWEEN NASA/INDUSTRY"</p> <p>DESIRED RESULTS (FIGURE I-4)</p> <p>...STEPS NEEDED TO PERFECT IDEAS"</p> <p>...FORTUNATE...IF...COME UP WITH NEW INNOVATIONS"</p> <p>...HIGH TECHNOLOGY"</p> <p>...NOT ARBITRARY RESEARCH"</p>	<p>CONTINUING IDEAS (FIGURE I-8)</p> <p>12 IDEAS IDENTIFIED, REQUIRING ZERO "G" OR ISOLATION FROM TERRESTRIAL ENVIRONMENT: INCLUDING PARTICLE MANIPULATION BY SMALL FORCES, VIBRATION TESTING OF FRACTIONAL HORSEPOWER ELECTRIC MOTORS, HIGH TEMPERATURE SINGLE CRYSTAL AND EUTECTIC TURBINE BUCKETS, HIGH PURITY TUNGSTEN X-RAY TARGETS, ETC.</p> <p>PARTICIPANTS (FIGURE I-5), IDENTIFIED IDEAS (FIGURE III-1), KNOWLEDGE/CAPABILITIES (FIGURE II-11). BENEFITS (FIGURE I-9).</p> <p>12 PARTICIPATING ORGANIZATIONS, 22 KEY INDIVIDUALS FOR CONTINUING IDEAS.</p> <p>FOR THE 12 CONTINUING IDEAS: ZERO "G" (TO AVOID CONVECTION, PRECIPITATION) IDENTIFIED 6 TIMES, (TO PROVIDE LEVITATION) IDENTIFIED 6 TIMES; VIBRATION AND ACOUSTIC ISOLATION (TO AVOID COUPLING) IDENTIFIED 4 TIMES; HARD VACUUM, AS A SECONDARY REQUIREMENT, (FOR PROCESS ENVIRONMENT) 4 TIMES, (AS CONTAMINATION CONTROL AID) 2 TIMES; ISOLATION FROM TERRESTRIAL ENVIRONMENT (TO AVOID BIORHYTHM CUES) 1 TIME.</p> <p>USER/KEY INDIVIDUALS/IDEA/REQUIREMENTS JUXTAPOSITION MAINTAINED THROUGHOUT STUDY</p> <p>ECONOMIC BENEFITS DERIVED FOR 9 OF 12 CONTINUING IDEAS, $> \\$1 \times 10^9$ / YEAR. SOCIOLOGICAL BENEFITS (OTHER THAN NATIONAL DEFENSE) DERIVED FOR 7 OF CONTINUING IDEAS, INCLUDING LOWER POLLUTION, LIVES SAVED, IMPROVED MEDICAL DIAGNOSES, HUMAN COMFORT AND SAFETY (FEW NUMERICAL ANSWERS)</p> <p>APPROACH (FIGURE II-1), STUDY LOGIC (FIGURE II-3), PARTICIPANTS (FIGURE I-5), USER ANALYSES (APPENDICES A-N), IDENTIFIED IDEAS (FIGURE III-1)</p> <p>STUDY APPROACH AND LOGIC PROVIDED 80 PARTICIPANTS, DIALOGS WITH 403 INDIVIDUALS, 120 IDEAS NOTED, 101 IDEAS IDENTIFIED, 14 SUPPORTIVE ANALYSES.</p> <p>7 OF 14 USER ANALYSES PERFORMED WITHOUT FUNDING</p> <p>SMALL, REPRESENTATIVE SAMPLE (80 ORGANIZATIONS IN 14 OF 27 BASIC INDUSTRIES) NOW AWARE OF POTENTIAL OF SPACE PROCESSING. SOME HAVE RESERVATIONS REGARDING LEGAL, FINANCIAL ASPECTS.</p> <p>BASIC DATA GENERATED (SECTION III), CONTINUING IDEAS (FIGURE I-8), IDENTIFIED IDEAS (FIGURE III-1).</p> <p>IDEAS COVER RANGE FROM MODIFIED RAW MATERIALS AND DESIGN DATA TO FINISHED COMPONENTS; ALSO REFLECT APPLICATIONS IN WHICH SPACE PORTIONS ARE INITIAL, INTERIM OR FINAL STEPS.</p> <p>NEW IDEAS: PARTICLE MANIPULATION BY SMALL FORCES, VIBRATION TESTING OF SMALL MOTORS, IMPRINTING OF CIRCUITRY FOR EXTREMELY HIGH FREQUENCY SURFACE ACOUSTIC WAVE COMPONENTS, HIGH SPECIFICITY SEPARATION OF ISOENZYMES WITH LARGE PORE GELS.</p> <p>EIGHT OF THE 12 CONTINUING IDEAS ARE CONSIDERED "HIGH TECHNOLOGY"</p> <p>CRITERION FOR DISCONTINUING IDEAS WHICH APPEARED TO BE RESEARCH ELIMINATED 4 IDENTIFIED IDEAS. 3 IDEAS, PARTICLE MANIPULATION BY SMALL FORCES, UTILIZATION OF BIORHYTHMS, AND BASIC HEAT TRANSFER DATA, RETAINED DUE TO HIGH LIKELIHOOD OF APPLICATIONS.</p>	<p>SUCCESSFUL - MORE STUDY REQUIRED TO ASSESS POSSIBILITIES OF ADDITIONAL 37 IDEAS.</p> <p>SUCCESSFUL - MORE STUDY ON ADDITIONAL 37 IDEAS WILL LIKELY ADD SPECIFIC USERS.</p> <p>SUCCESSFUL - NEW AREA OF VIBRATION AND ACOUSTIC ISOLATION WILL LIKELY ADD SPECIFIC KNOWLEDGE/CAPABILITIES REQUIREMENTS. MORE STUDY REQUIRED TO UNCOVER KNOWLEDGE/CAPABILITIES INHERENT IN OTHER SPACE "PROPERTIES" (TOTAL SOLAR SPECTRUM, REENTRY CONDITION, PARTICULATE RADIATION, ETC.)</p> <p>SUCCESSFUL</p> <p>MODERATELY SUCCESSFUL - NOT ALL ELEMENTS OF ALL USER CHAINS ANALYZED. MORE STUDY NEEDED, ESPECIALLY ON SOCIOLOGICAL BENEFITS.</p> <p>SUCCESSFUL - $> 90\%$ OF INITIAL CONTACTS PRODUCED PARTICIPANTS.</p> <p>MODERATELY SUCCESSFUL - LIMITED VERBAL COMMITMENTS, NONE DOCUMENTED.</p> <p>MODERATELY SUCCESSFUL - MORE NASA/INDUSTRY INTERFACING REQUIRED ON BUSINESS PLANNING QUESTIONS.</p> <p>SUCCESSFUL</p> <p>SUCCESSFUL - TECHNOLOGY ANALYSES REQUIRED TO "PROVE OUT" SOME OF THESE</p> <p>SUCCESSFUL - NOTE: IDEA NO. 5, VIBRATION TESTING OF FRACTIONAL HORSEPOWER ELECTRIC MOTORS IS EXAMPLE OF "LOW" TECHNOLOGY WITH HIGH POTENTIAL BENEFITS.</p> <p>SUCCESSFUL - OF COURSE SOME RESEARCH PROGRAMS WILL BE REQUIRED FOR VERIFICATION TESTING RELATED TO THE IDENTIFIED IDEAS.</p> <p>Σ SUCCESSFUL STUDY - APPROACH REACHED 80 ORGANIZATIONS REPRESENTING 14 OF 27 BASIC INDUSTRIES. DIALOG TECHNIQUE ELICITED 120 IDEAS OF WHICH 12 WERE WORTHWHILE. ZERO "G" MOST CRITICAL NEED. OTHER REQUIREMENTS FOR VIBRATION ISOLATION, ISOLATION FROM TERRESTRIAL ENVIRONMENT, HARD VACUUM. POTENTIAL BENEFITS EXCEED $\\$1 \times 10^9$ PER YEAR PLUS SOCIOLOGICAL.</p>

Figure IV-1. Conclusions -- Results Vis-A-Vis Aims of Study

To the level of technical analysis feasible for this study, we believe we have successfully maintained the Study Theme. All of the 12 "Continuing Ideas" and the vast majority of the remaining 89 are for products, processes or services needed on the ground. Furthermore, when it could be determined that development or production in space facilities was not required, such Ideas were dropped.

The "specifics" established in the Study Objectives were successfully identified; User, knowledge/capabilities, their relationships. In "Potential Benefits" we can only claim moderate success. The number of "Continuing Ideas," the complex of potential Users, and the alternative choices available to most Users as to mode of utilizing new capabilities, combine into such a large number of permutations as to make it unfeasible to identify all possible benefits. We were able, however, to identify a number of key economic and sociological benefits. The potentially more than billion-dollars-per-year gained, thousands of lives saved, tons of pollution reduced, are, because of the small sample and conservative estimation guidelines, felt to be "a drop in the bucket" compared to the full potential of benefits.

Insofar as the NASA intent for the study, we judge our effort to be moderately successful. Our approach gained and maintained the interest and aid of a large body of non-aerospace organizations. However, solid commitments from such organizations to pursue further effort, should the identified Ideas prove feasible, were not obtained. This was due, mainly, to a lack of technical, legal and financial information. On the other hand, a few organizations carried on analyses for the study without funding, which implies the sought-for initiative. The information exchange between the Study Team and participating organizations was all that was desired. Information exchange of industry with NASA, however, needs work. A number of key questions by commercial industry, to which we supplied temporizing answers, need realistic answers for integration into Industries' future business planning.

We believe that the Desired Results noted by NASA, have all been met successfully. The range of identified Ideas covers partial to complete processes, including those in which the space process is an intermediate step. Several Ideas that were identified have not been documented heretofore. Furthermore, not only have we pinpointed some potentially valuable

"high technology" Ideas, but also a "low technology" Idea with a potentially high payoff. Finally, we deliberately overcompensated in our effort to avoid "research for research sake."

In summary, we feel the study was successful. Our chief conclusions are that these are products, processes and services that will require development or production in space, and that their values will be in the billions of dollars, thousands of lives saved, etc. Further, we conclude that non-aerospace industry will very likely support a program aimed at such development and production, once they are provided with business planning data. Finally, we conclude that zero "G" is the most critical need for such development and production, with isolation from other terrestrial environments a distant, but growing, second, and that considerable analytical and experimental effort is required to assess the feasibility of the Ideas identified herein.

IV.2 RECOMMENDATIONS

The Study results are such that NASA can, and should, utilize them as a basis for maintaining and building a relationship with non-aerospace organizations (especially commercial), that ultimately will benefit the U. S. through the efficient transfer of newly acquired technology in space to the products, processes and services utilized by consumers on the ground.

Industries (owned by stockholders who seek reasonable dividends balanced with acts of good corporate citizenship) will, in general, be inclined to favor such a relationship, if supplied with sufficient information to plan their participation.

NASA should, therefore, consider steps to make such information available.

1. Pertinent information (that which directly influences specific industries) should, of course, be disseminated via various news and trade media.
2. Further studies, such as this Phase I, should seek to involve additional potential Users.
3. Business Planning Studies, to provide specific organizations and NASA with technical, resources, and marketing data in support of decisions for future commercial ventures in space, should be initiated with specific potential User organizations. Such studies would go far toward answering a number of key questions, Figure IV-2, posed by many of the participating User organizations during the Phase I study. These questions were expressed in more than passing fashion, and reflect, not only a concern for present effort, but for future planning. If NASA views this concern as an indication of interest in future participation by industry, then it should consider initiating the recommended Business Planning Studies. These studies, and answers to the listed questions should be expected, not to assure industry that all arrangements and relationships will be resolved in modes that are optimum for industry, but rather to derive decision data. Industry (especially commercial industry) requires such data to estimate the risks (financial, legal, technical) involved in pursuing such ventures. The normal 5 to 10 year industry planning of new projects will consider a number of ventures with varying degrees of risk. What is needed, is data to assess that risk.
4. On the technology side, the analyses, ground experiments, and where pertinent, initial space experiments should be carried out with the participation of specific potential User organizations to check the feasibility of Ideas, and verify the resulting concepts. In some cases, it may well be necessary to initiate studies on what the requirements for such experiments should be, and where they fit into the total scheme of development. Such requirements and planning data should be derived with potential User organizations' aid.

HOW WILL NASA HANDLE MY PROPRIETARY DATA
(OR EQUIPMENT)?

WHAT RIGHTS WOULD NASA RETAIN ON MY DATA
(OR PATENTS, OR PRODUCTS)?

WHO PAYS FOR SPACE EXPERIMENTS (OR TEST, OR
EQUIPMENT) TO DEVELOP MY PRODUCT (OR PROCESS
OR SERVICE)?

WHAT ROLE DOES NASA (OR GE) PLAY IN PROGRAM
SUBSEQUENT TO B. U. S. ?

WHAT IS THE PROBABILITY THAT THERE WILL BE A
SHUTTLE (OR SPACE FACILITY)?

WHEN DO DECISIONS TO GO AHEAD NEED TO BE MADE?

HOW MUCH WILL IT COST TO RUN AN EXPERIMENT OR
OBTAIN FACILITY SPACE?

Figure IV-2. Typical Questions

5. As a final recommendation, NASA should review the legal aspect of the questions listed in Figure IV-2. Industry is well aware of NASA "rights" usually specified in NASA contracts, including disclosure regulations, patent ownership, etc. In commercial industry, data, processes, patents, etc., are the lifeblood of a company. The competitive character of commercial industry may not be compatible with the standard "rights" clauses, etc. It is therefore recommended that all such legal and financial policies and posture be reviewed by NASA to determine whether the desired NASA/Industry relationships for furthering the Beneficial Uses of Space might not be more rapidly, efficiently, and universally established through modification of such policies and posture, or at least through publicized interpretation as to their intent.

In consonance with this latter suggestion, NASA has extended the Study for Identification of Beneficial Uses of Space to a Phase II effort, in order to obtain representative Experiment Requirements and Planning Data.

The objectives of Phase II are shown in Figure IV-3. The Phase I Ideas selected for Phase II are shown in Figure IV-4. The overall approach for Phase II is shown in Figure IV-5. The Phase II Schedule is shown in Figure IV-6.

FOR FOUR SELECTED IDEAS FROM PHASE I:

1. SELECTION OF BEST APPROACH FOR IMPLEMENTATION OF EACH IDEA
2. DEFINITION OF REQUIREMENTS FOR EXPERIMENTS TO VERIFY SELECTED APPROACH - INCLUDING MISSION PROFILES, TYPES OF VEHICLES AND GROUND FACILITIES
3. ESTABLISHMENT OF TECHNICAL TIMELINES AND MILESTONES TO ACHIEVE OPERATION (PRODUCTION, OR SERVICE) OF PROTOTYPE FACILITY/PILOT PLANT
4. FORMULATION OF PLANNING PROFILES TO RELATE KEY MANAGEMENT DATA TO TECHNICAL TIMING. DATA TO INCLUDE DEVELOPMENT STEPS, DECISION POINTS, ALTERNATIVES, RISKS, MAJOR FACILITIES, UNIQUE MANPOWER

Figure IV-3. Phase II Objectives

IDEA	COMPANY	KEY INDIVIDUAL
1. SURFACE ACOUSTIC WAVE ELECTRONICS	GE-ELECTRONICS LABORATORY	DR. S. TEHON
2. SEPARATION OF ISOENZYMES	POLYSCIENCES, INC.	DR. D. HALPERN
3. HIGH PURITY TUNGSTEN X-RAY TARGETS	GE-MEDICAL SYSTEMS DIVISION	MR. R. HUESCHEN
4. TRANSPARENT OXIDE MATERIALS	CORNING GLASS	DR. G. McLELLAN

Figure IV-4. Selected Ideas for Phase II Study

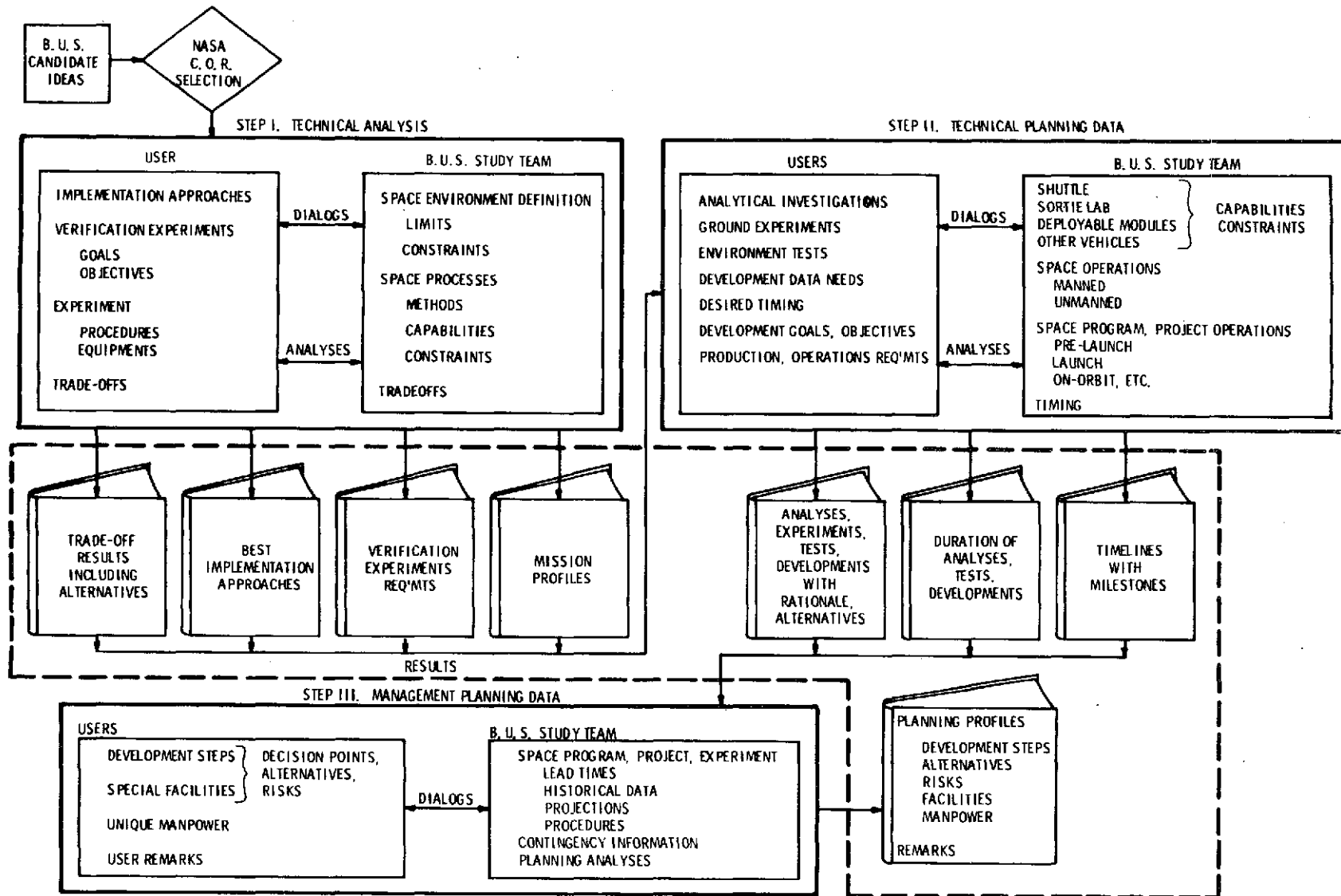


Figure IV-5. Study Approach

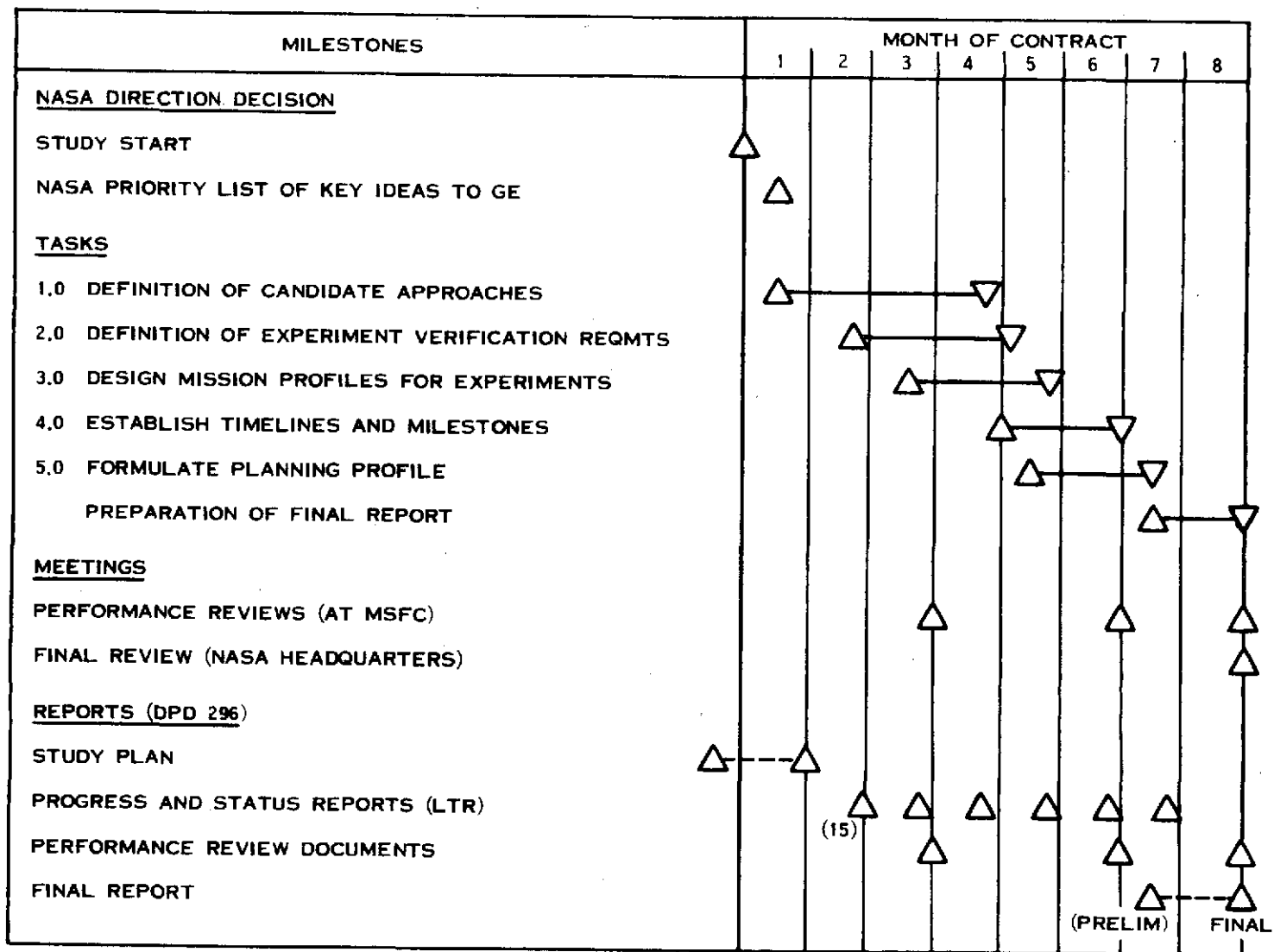


Figure IV-6. Milestone Schedule - Phase I